Impact of climate change and management on soil characteristics and qualities

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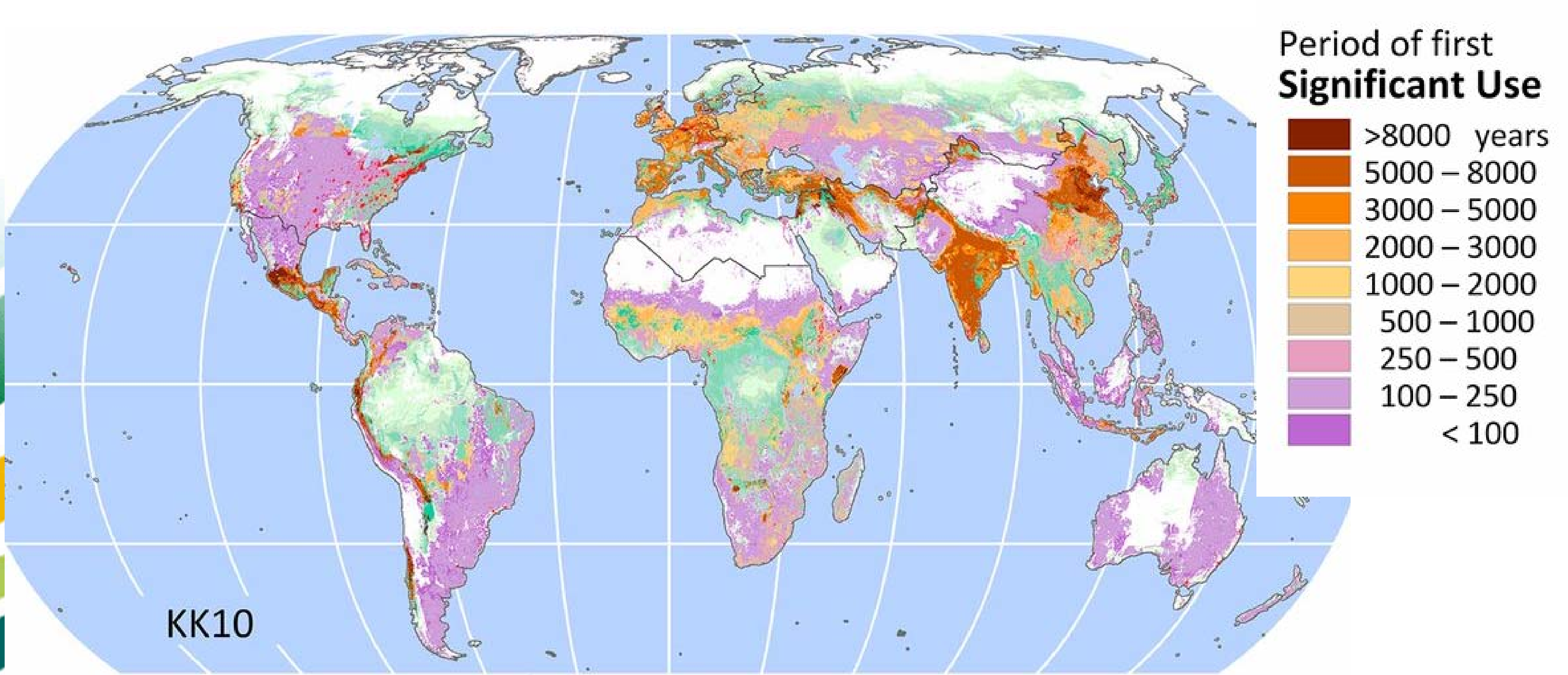
CONSIGLIO PER LA RICERCA
E LA SPERIMENTAZIONE
IN AGRICOLTURA

In this talk

- Soil ecosystem services, soil degradation processes, land use and management
- Some research results on:
  - 1) SOC spatial and temporal variations caused by climate and management
  - 2) Future scenarios of SOC stocks in different cropping systems

Time period of first significant land use, based on historical reconstructions



Erle C. Ellis et al. PNAS 2013;110:7978-7985

Soil ecosystem services

PROVISION
Biomass (food and fiber)
Building materials and fuel

REGULATION
Regulation of the water cycle
And of sediment (soil erosion)

SUPPORT
Structures and infrastructures

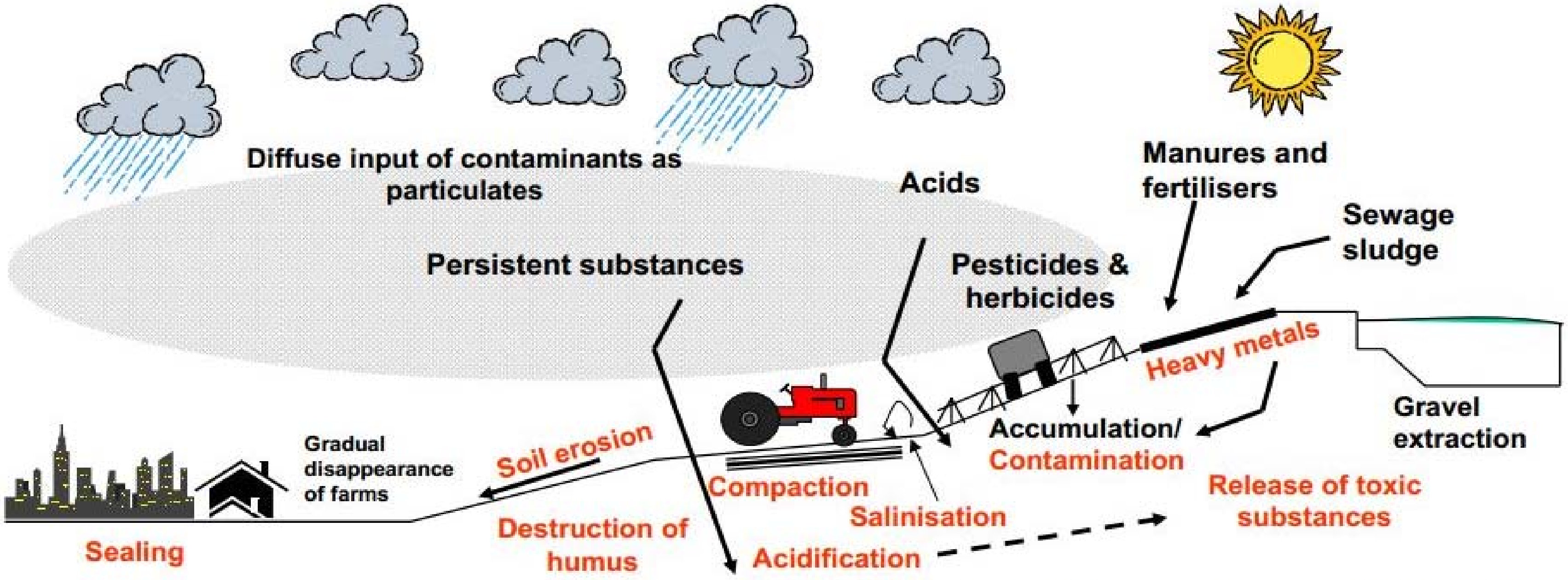
PROTECTION

AIR QUALITY AND CLIMATE
GHG emissions
Carbon sequestration

CULTURAL
Cultural heritage, conservation of archaeological finding

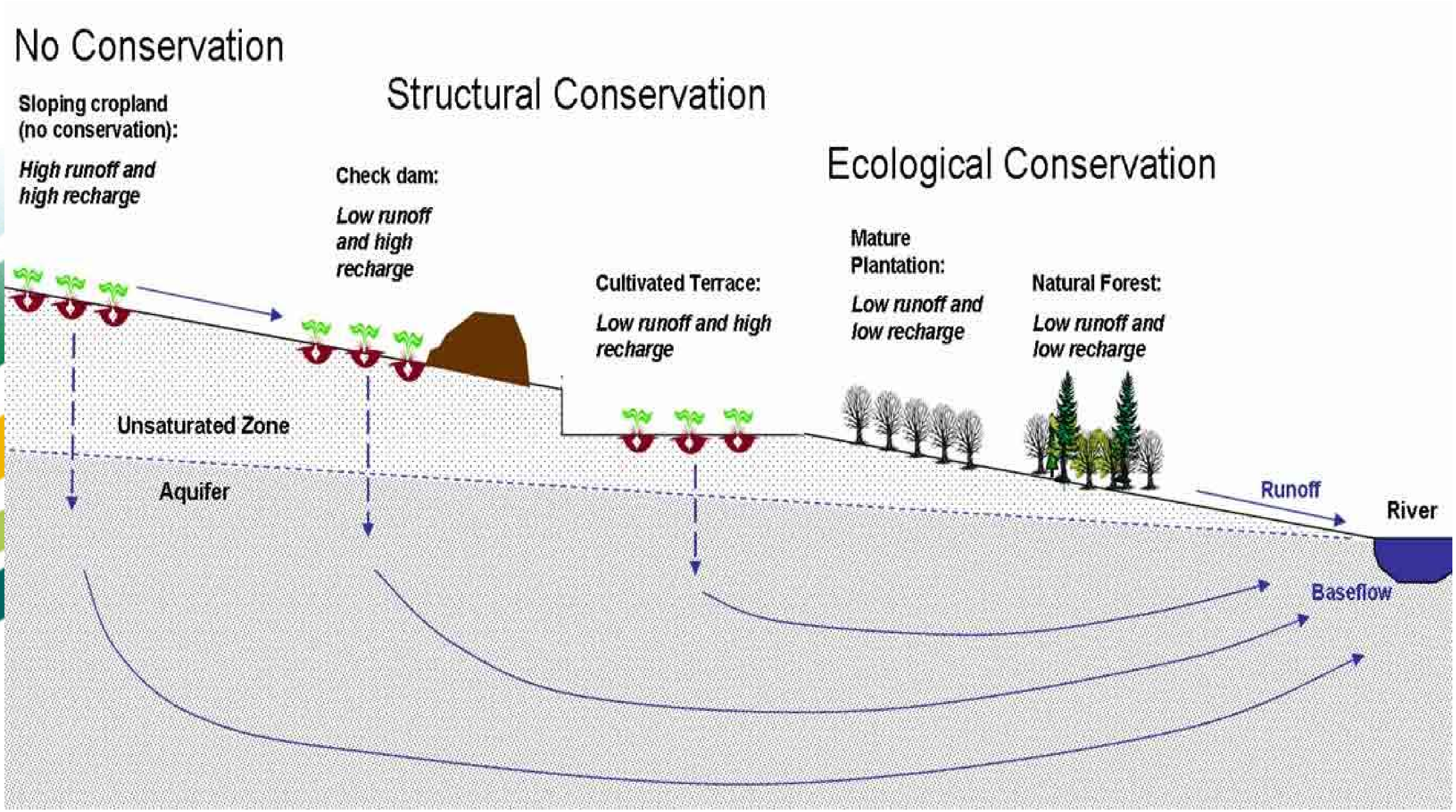
BIODIVERSITY

Local soil degradation causes and processes

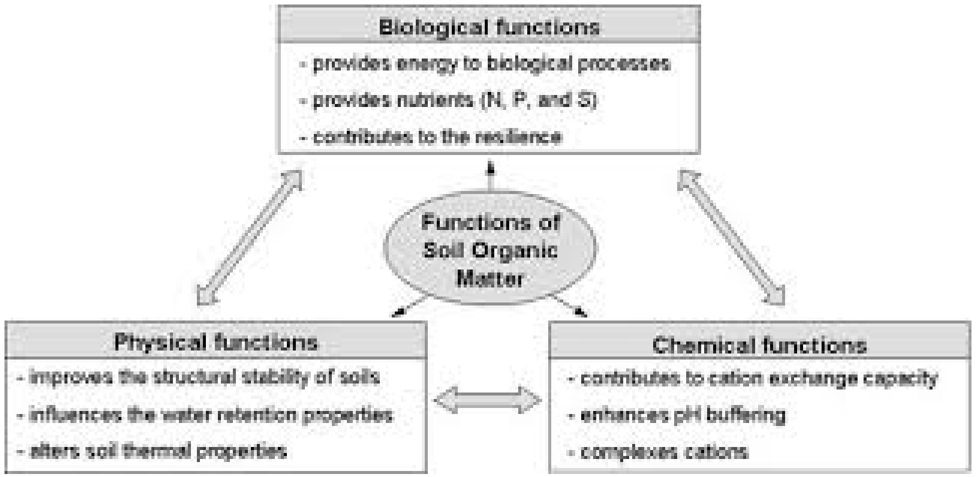


Blocking of soil functions important to the ecology of the landscape Destruction of soil	Gradual destruction of soils Reduction in soil fertility	Changes in the structure of soils Reduction in soil fertility	Contamination of soils and ground water with applied agrochemicals and atmospheric pollutants Changes in soil composition Adverse impacts on living organisms in the soil	Destruction of soil

Water runoff in different types of soil conservation

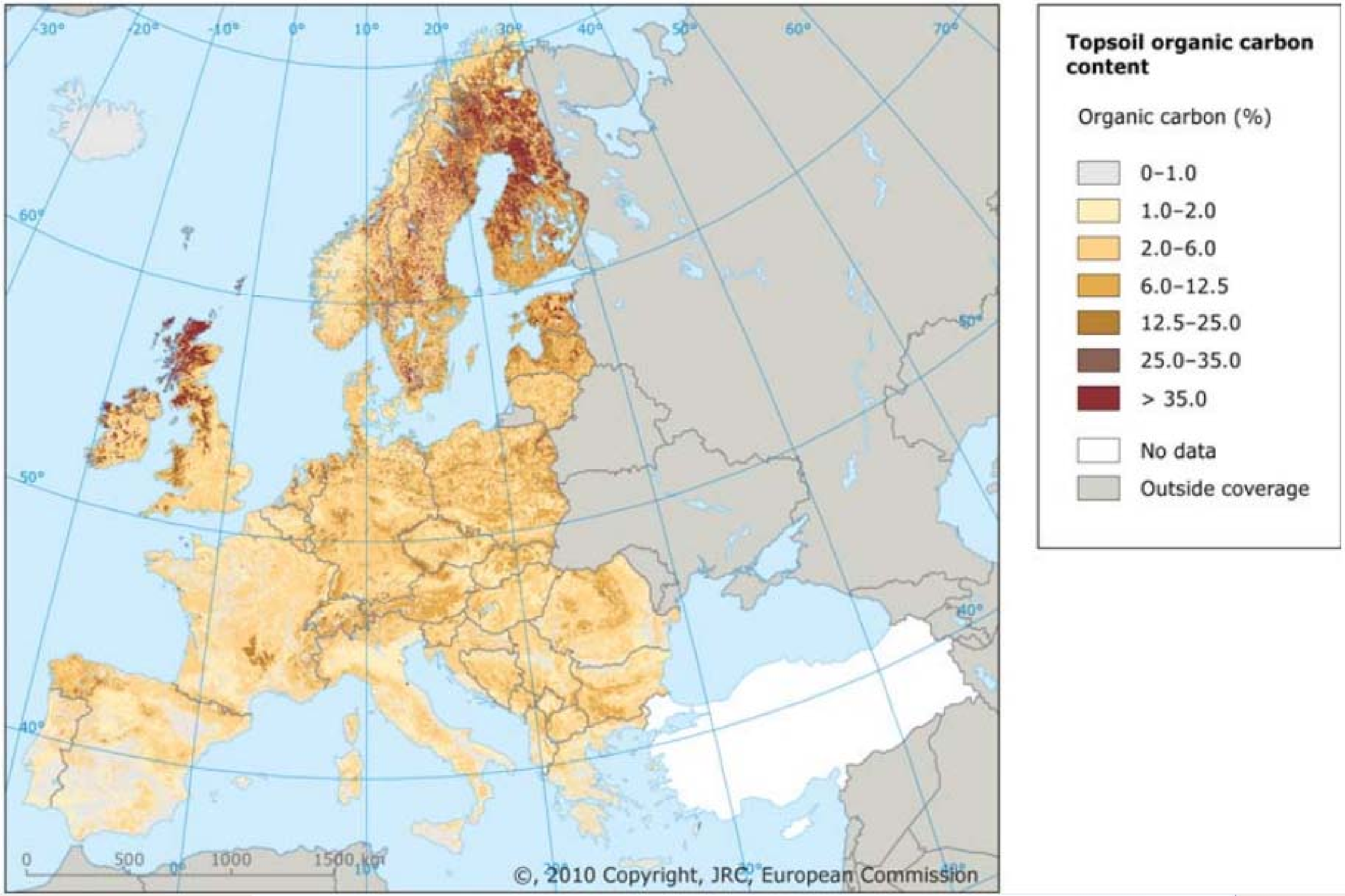


Soil organic carbon (SOC) dynamic

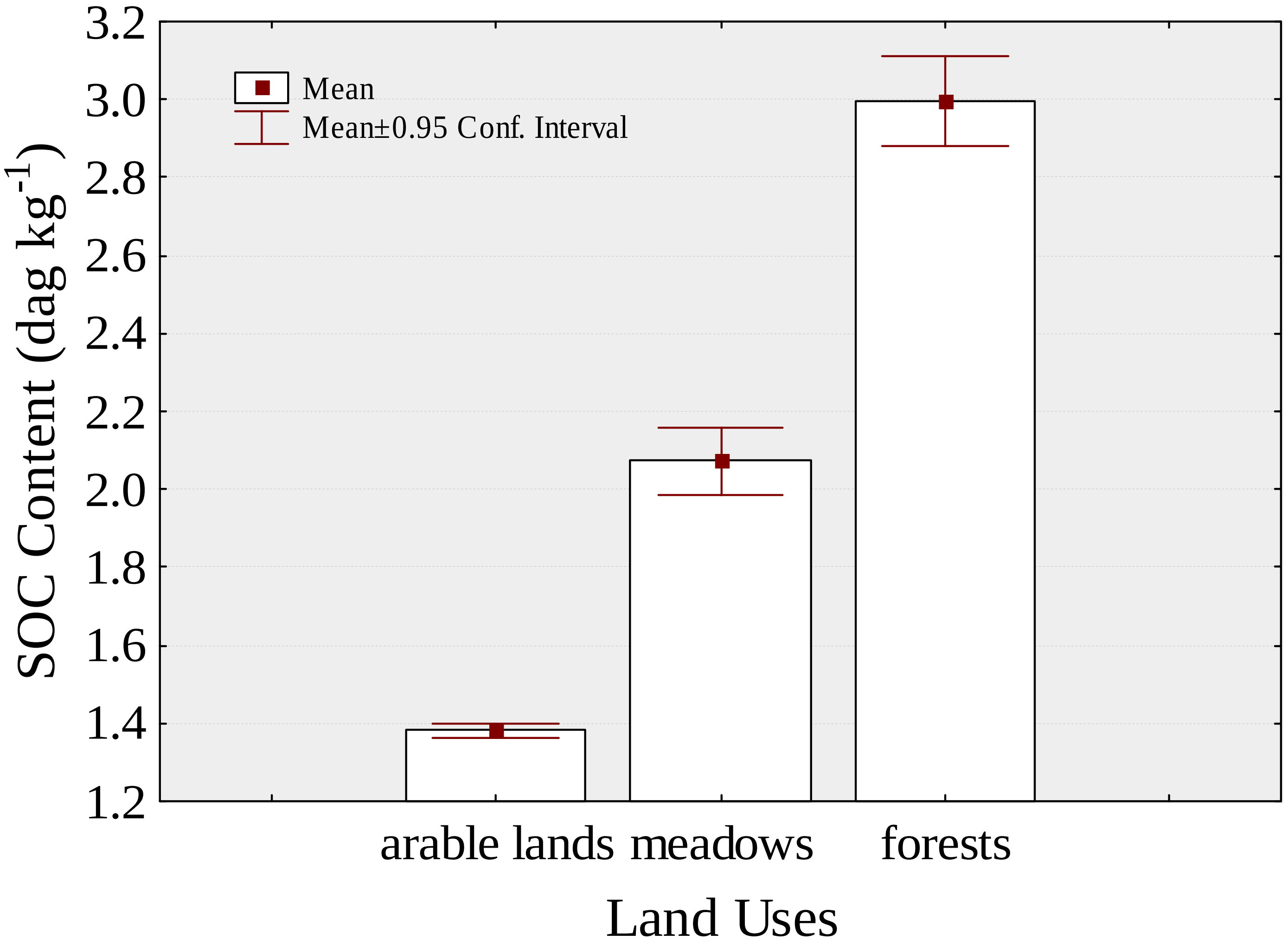


A major threat to soil functions: Loss of organic matter

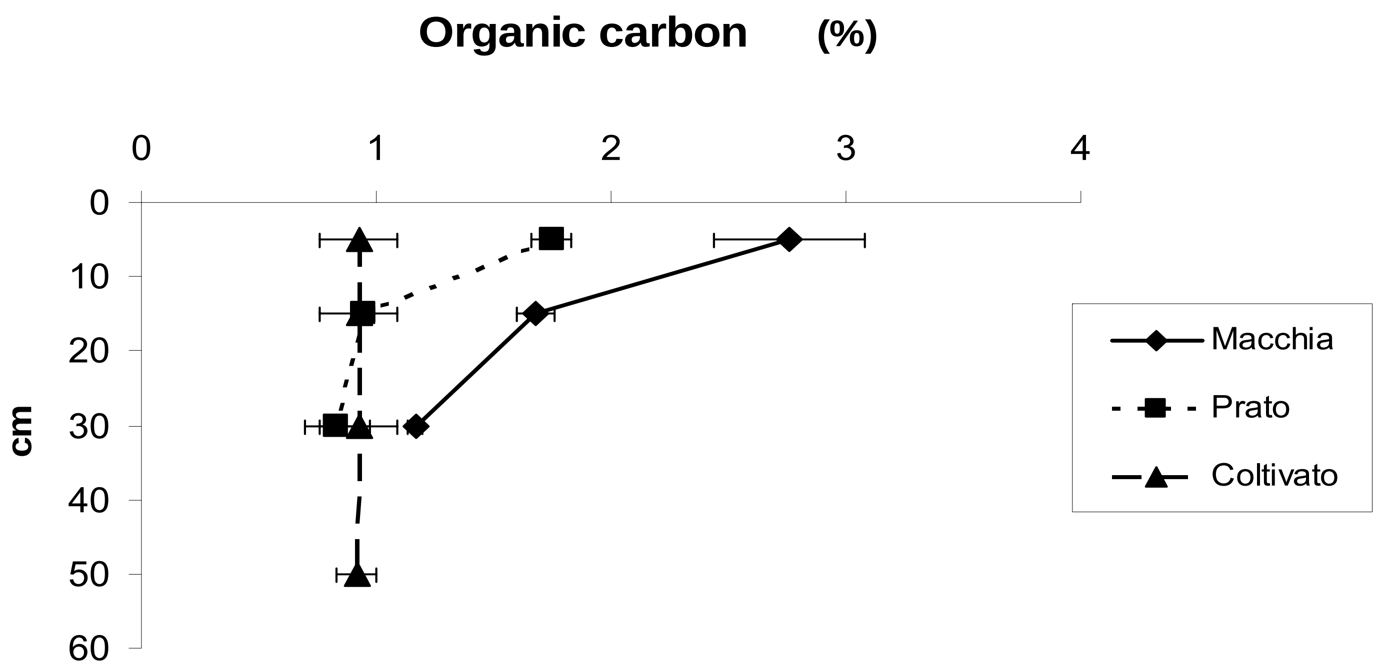
Most of European soils have less than 2% of SOC in the first 30 cm (source: JRC, 2010)



SOC (dag kg-1) and main land uses of Italy



Organic carbon profile and land use in Vertic Cambisols



SOM, Agricultural land uses, first 30 cm

	O.M.	n	st.er.
Irrigated row crops	1,59	21	0,17
Vineyards	1,90	1225	0,05
Olive tree groves	1,91	1405	0,03
Mixed cultivation	1,96	343	0,08
Paddy rice	2,04	129	0,15
Urban areas	2,05	65	0,19
Vegetables	2,06	192	0,12
Not irrigated row crops	2,24	8548	0,02
Scarcely vegetated areas	2,39	106	0,22
Meadows	2,69	1815	0,05
Orchards	2,84	1031	0,11
Humid areas	3,57	14	1,29
Prairies of high mountain	3,59	672	0,13
Permanent meadows	3,96	2019	0,10

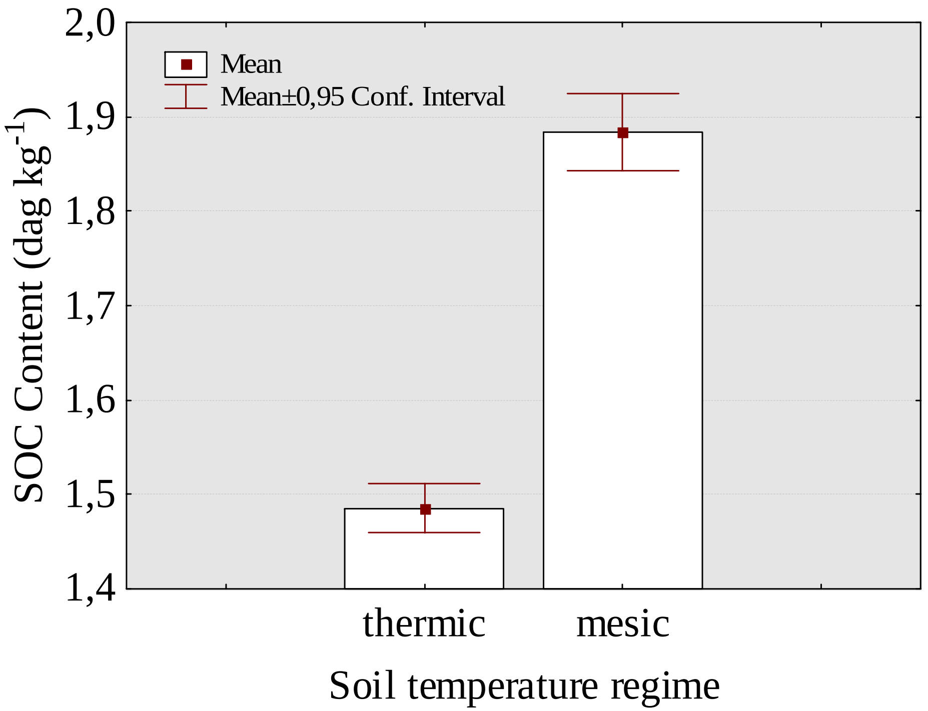
Effect of irrigation (7,339 sites)

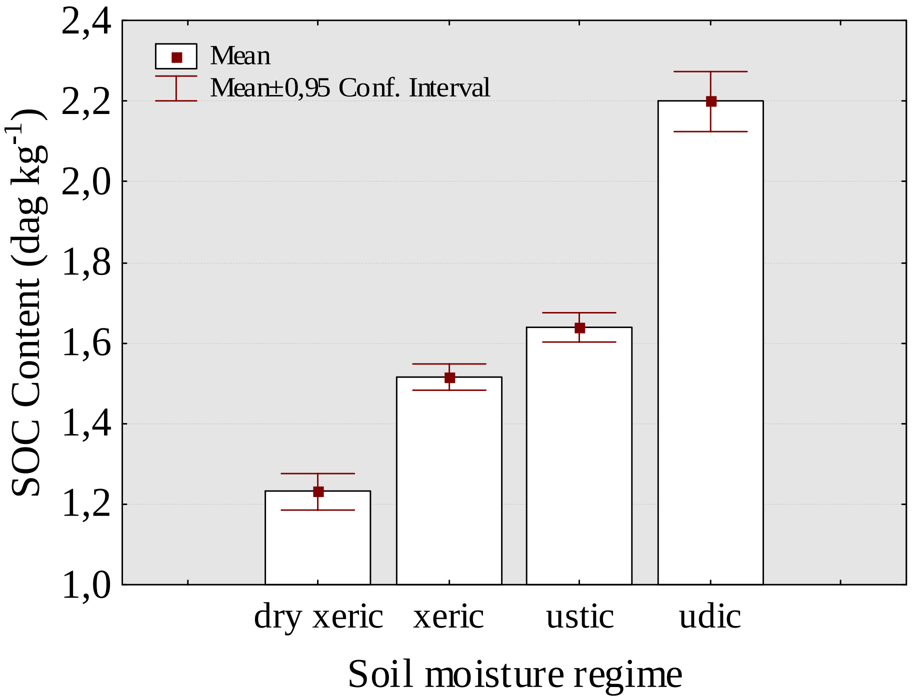
Crop	O.M. %	n	Stand. Err.
Irrigated vegetables	1.84 b	109	0.09
Not irrigated	2.55 a	80	0.28
Irrigated row crops	1.96 b	1517	0.04
Not irrigated	2.06 a	2288	0.03
Irrigated olive tree groves	2.00 a	472	0.07
Not irrigated	2.08 a	855	0.05
Irrigated vineyards	2.05 a	405	0.08
Not irrigated	2.06 a	438	0.09
Irrigated meadows	2.24 b	217	0.19
Not irrigated	2.48 a	392	0.17
Irrigated orchards	2.39 b	277	0.12
Not irrigated	2.80 a	289	0.13

Conclusions (1)

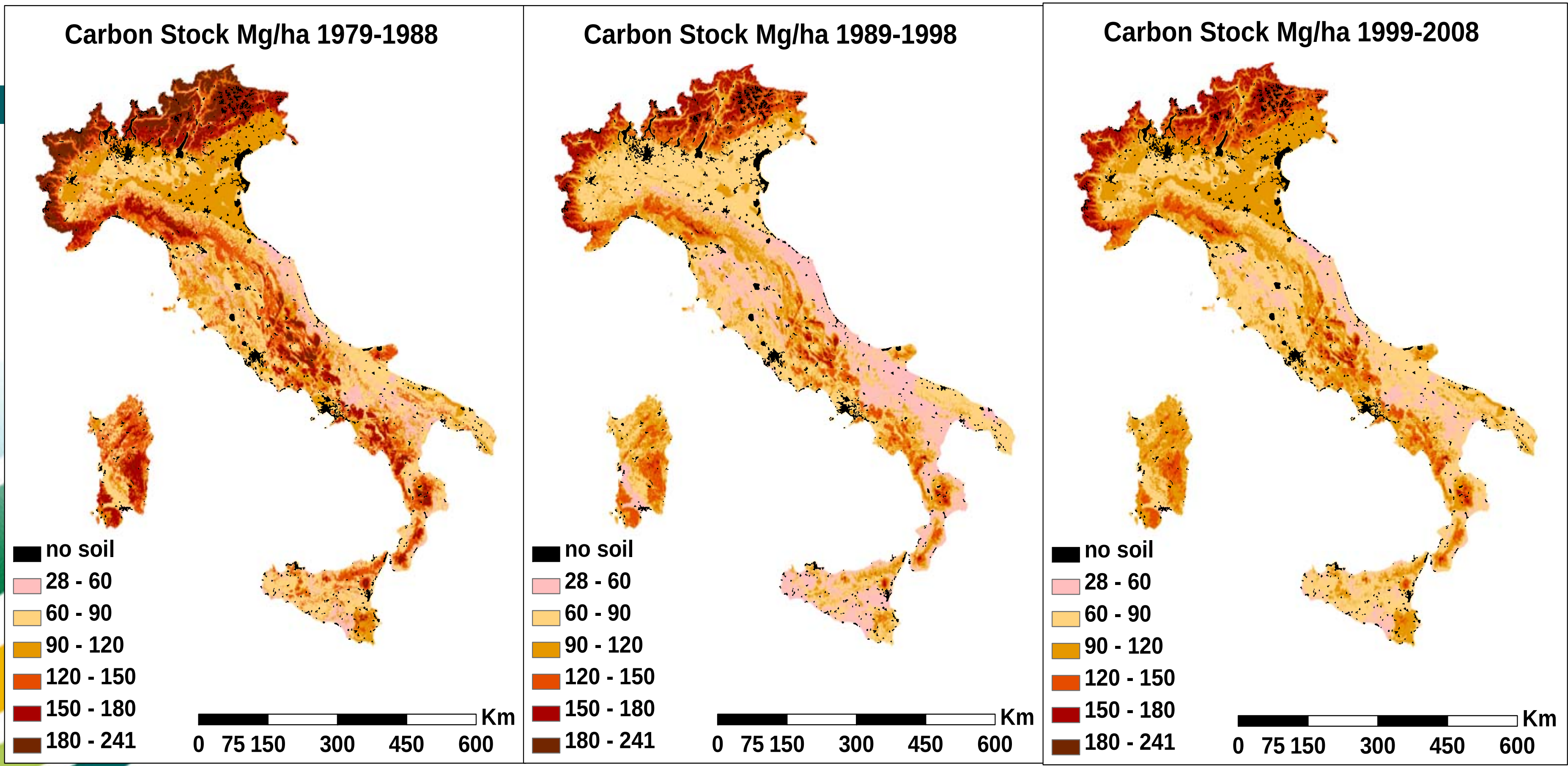
- Land use and management are important causes of SOC variations
- The more intesive the land use and management form, the more the SOC losses, but:
- There are management forms that can limit SOC losses

SOC variations and climate





And time?



Total CS 3.32 Pg	**Total CS** 2.74 Pg	**Total CS** 2.93 Pg
Mean CS 107 Mg hm^{-2}	**Mean CS** 88 Mg hm^{-2}	**Mean CS** 95 Mg hm^{-2}

M. Fantappiè, G. L'Abate, and E.A.C. Costantini, 2011 Factors Influencing Soil Organic Carbon Stock Variations in Italy During the Last Three Decades. In: P. Zdruli et al. (eds.), Land Degradation and Desertification: Assessment, Mitigation and Remediation, Springer, 435-465. doi 10.1007/978-90-481-8657-0_34.

Do climate changes affect SOC?

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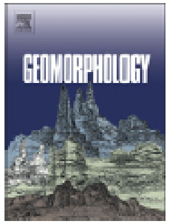
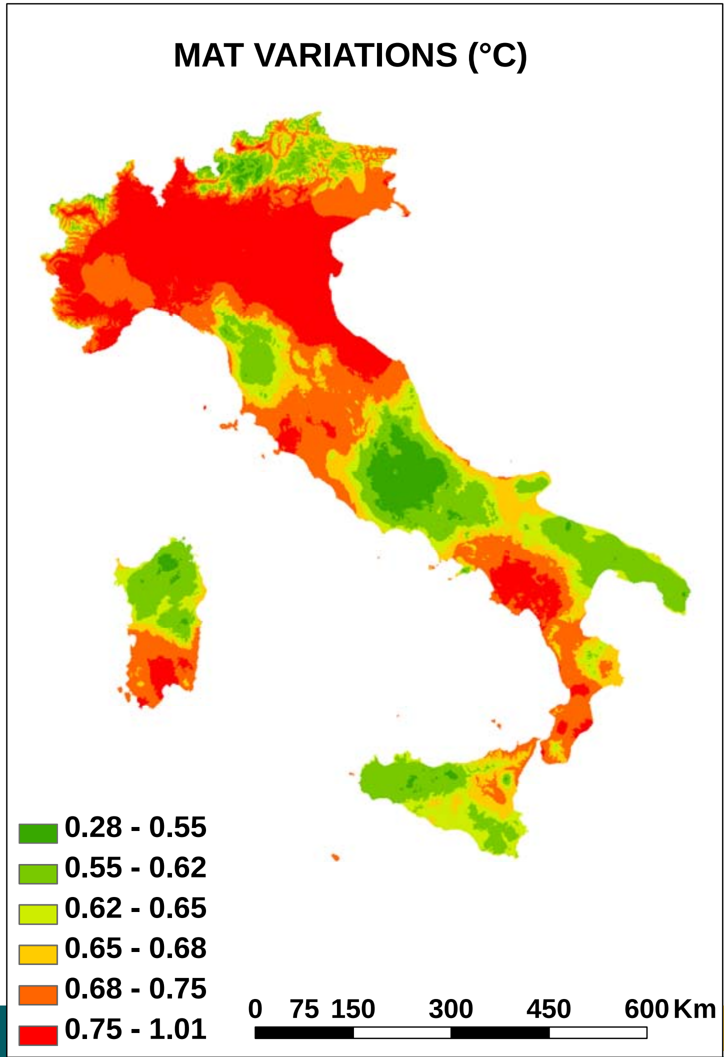


The influence of climate change on the soil organic carbon content in Italy from 1961 to 2008

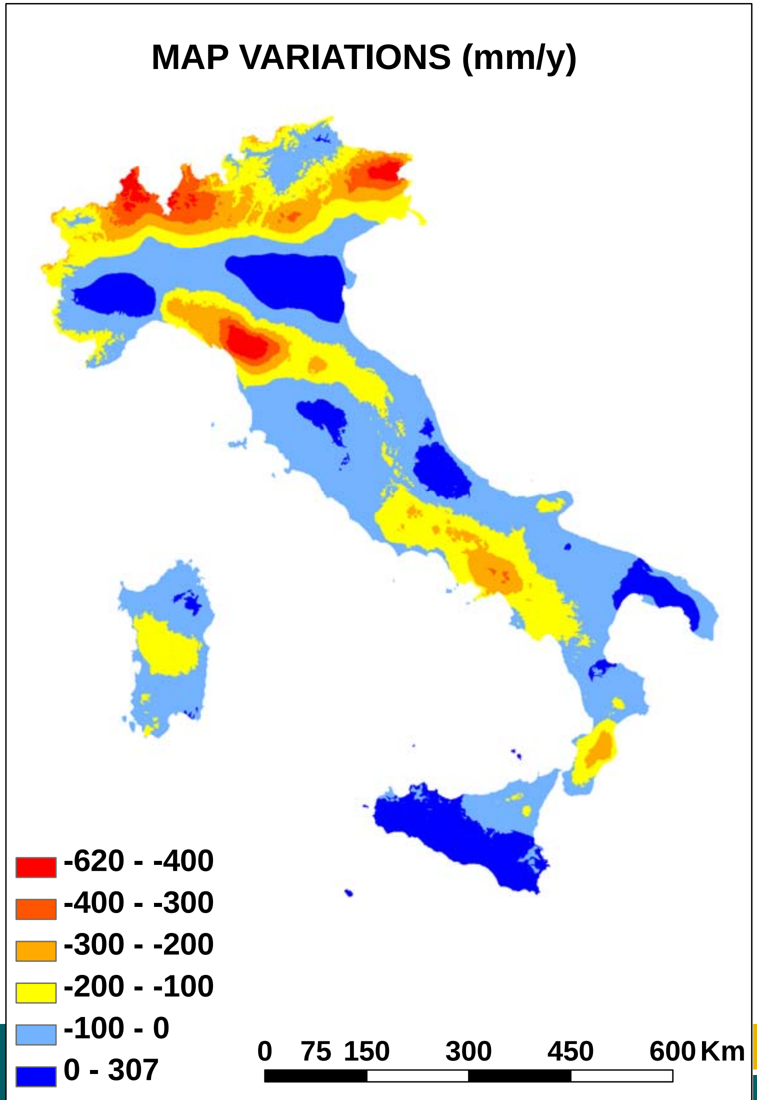
M. Fantappiè *, G. L'Abate, E.A.C. Costantini

CRA-ABP; Research Centre for Agrobiology and Pedology, 50121, Firenze, Italy

Mean annual air temperatures variations between 1961-1990 and the years 1991-2006 (C).



Mean total annual precipitations variations between 1961-1990 and the years 1991-2006 (mm year-1)



Multiple linear regression Model1

Variables		Coefficients	t-values	p-values
Categorical variables				
PERIOD 1961-1990 arable lands (Intercept)		2.367	22.789	< 0.001
Soil regions	1	-0.158	-2.162	0.030598
	…	…	…	…
	15	-0.581	-7.589	< 0.001
Lithology Groups	1	0.091	2.428	0.015203
	…	…	…	…
	4	0.488	9.648	< 0.001
Soil mosture regimes	udic	-0.230	-2.449	0.014341
	ustic	-0.242	-3.380	< 0.001
	xeric	0.047	0.863	0.388169
SOTER classes groups	1	-0.146	-4.721	< 0.001
	…	…	…	…
	6	2.150	10.578	< 0.001
Land uses	forests	1.111	17.265	< 0.001
	meadows	0.484	6.331	< 0.001
PERIOD 1991-2006		-0.180	-4.700	< 0.001
Continuous variables normalized				
Mean annual soil. temp. at 50 cm		0.166	9.132	< 0.001
Soil aridity index		-0.129	-4.311	< 0.001
Slope		0.048	2.984	0.002854
Periods/Land use interaction				
PERIOD 1991-2006	forests	-0.346	-4.779	< 0.001
	meadows	-0.324	-3.867	< 0.001

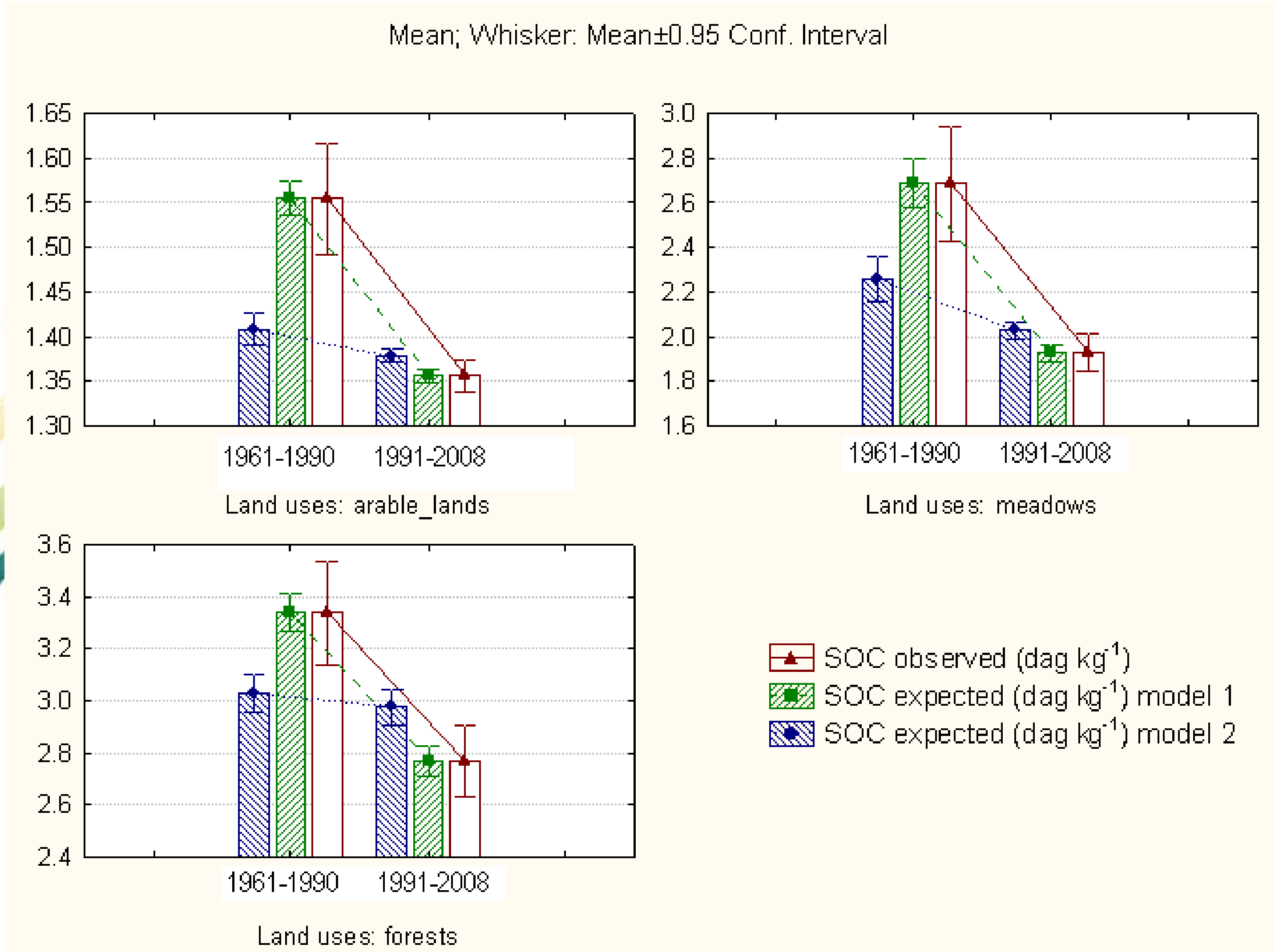
Residual standard error: 1.418 on 17802 degrees of freedom. Multiple R-Squared: 0.2696. Adjusted R-squared: 0.2681. F-statistic: 177.6 on 37 variables and 17802 DF, p-value: < 0.001

Multiple linear regression Model2

Variables		Coefficients	t-values	p-values
Categorical variables				
(Intercept)		1.899	17.175	< 0.001
Soil regions	1	-0.347	-4.779	< 0.001
	…	…	…	…
	15	-0.629	-8.164	< 0.001
Lithology Groups	1	0.062	1.634	0.10218
	…	…	…	…
	4	0.530	10.452	< 0.001
Soil moisture regimes	udic	0.000	0.004	0.99969
	ustic	-0.041	-0.529	0.59683
	xeric	0.187	3.120	0.00181
SOTER classes groups	1	-0.080	-2.606	0.00917
	…	…	…	…
	6	3.512	20.628	< 0.001
Land uses	forests	1.021	22.025	< 0.001
	meadows	0.292	6.580	< 0.001
Continuous variables normalized				
Mean annual soil. temp. at 50 cm		0.150	7.900	< 0.001
Soil Aridity Index		-0.059	-1.665	0.09593
Slope		0.031	2.021	0.04332
Climate/Land use interaction				
MAT (norm.)	arable lands	-0.003	-0.052	0.95840
	forests	-0.638	-7.853	< 0.001
	meadows	-0.218	-2.501	0.01238
MAP (norm.)	arable lands	0.085	2.686	0.00723
	forests	0.001	-0.519	0.60353
	meadows	0.054	-0.647	0.51772
MAT*MAP (norm.)	arable lands	-0.064	-1.720	0.08541
	forests	-0.282	-3.977	< 0.001
	meadows	-0.248	-3.038	0.00238

Residual standard error: 1.425 on 17797 degrees of freedom. Multiple R-Squared: 0.2626. Adjusted R-squared: 0.2608. F-statistic: 150.9 on 42 variables and 17797 DF, p-value: < 0.001.

Observed and modeled SOC

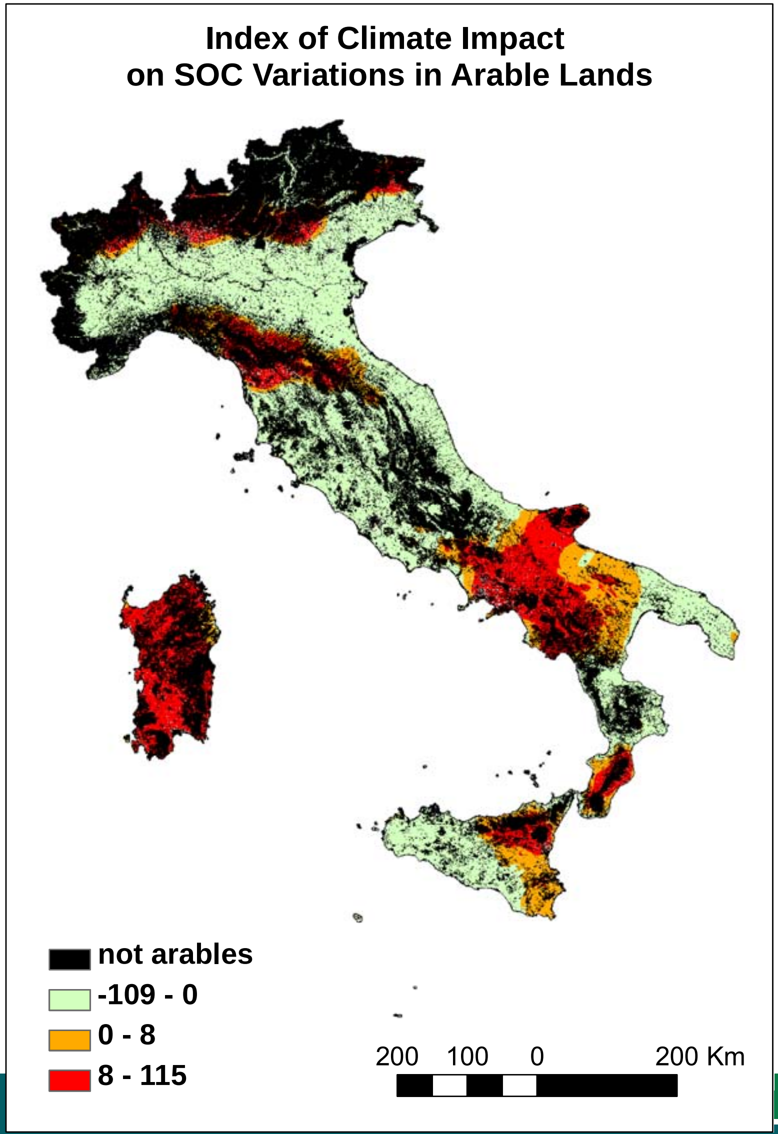


Index of climatic influence on SOC variations between the years 1961-1990 and 1991-2006

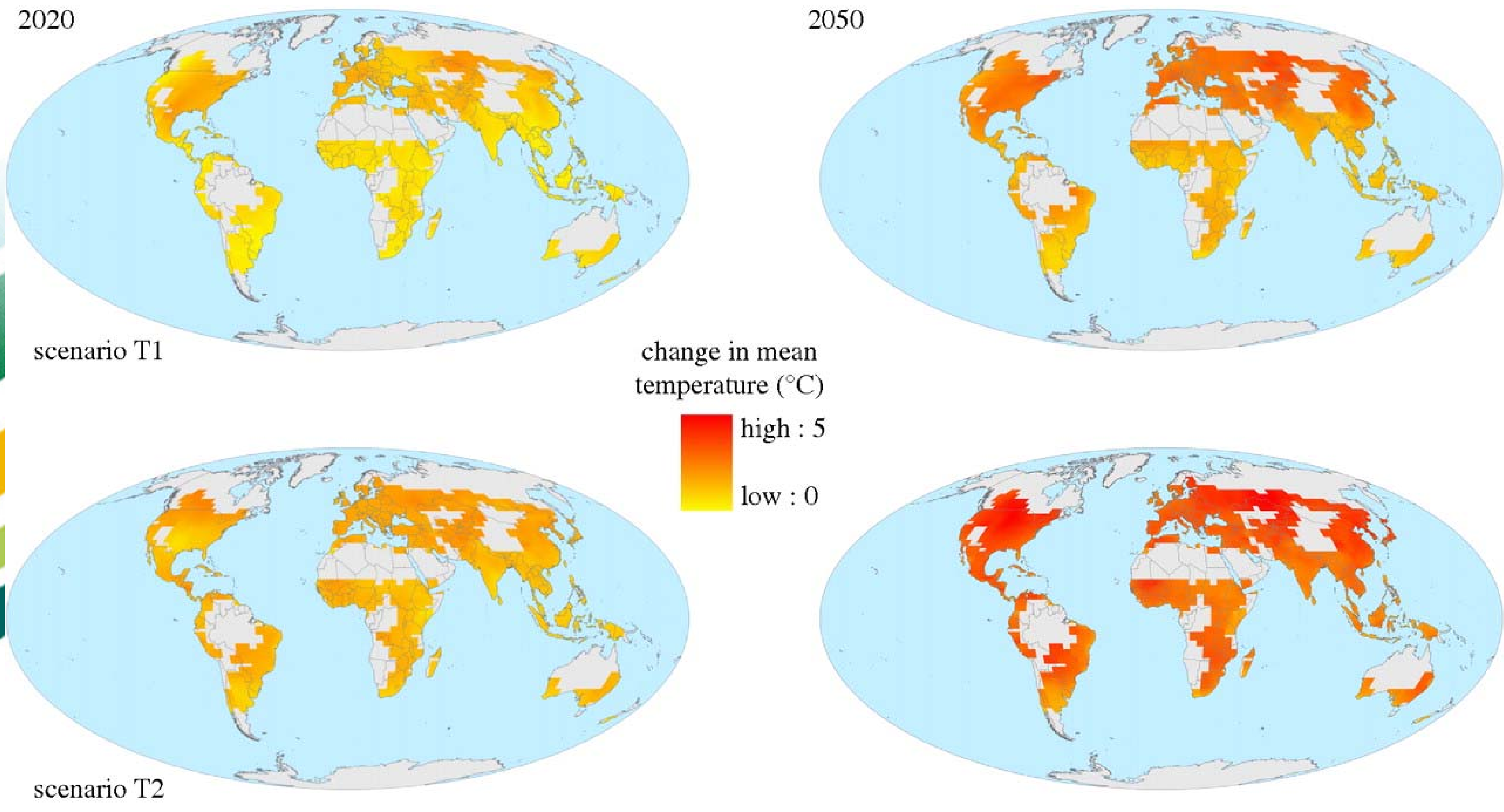
Ic = SOC Model2 / SOC Model1

Mean Ic Indexes (%):

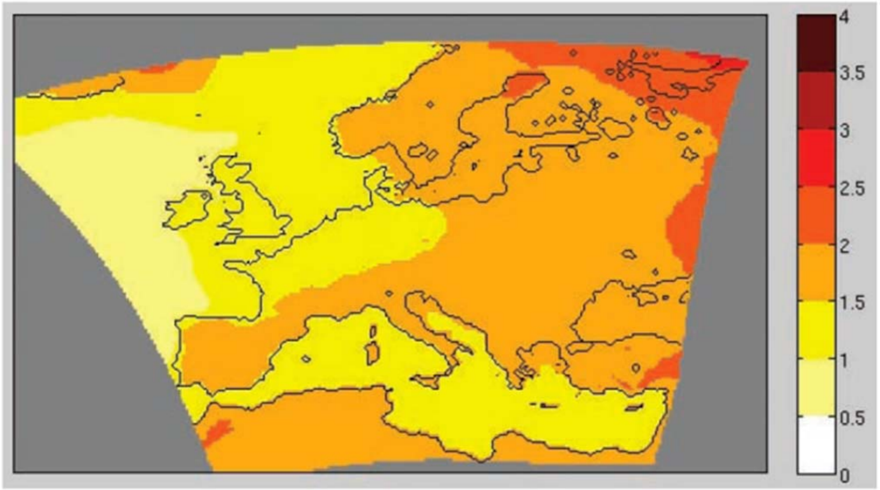
- 34.5 in meadows;
- 16.8 in arable lands;
- 11.6 in forests.

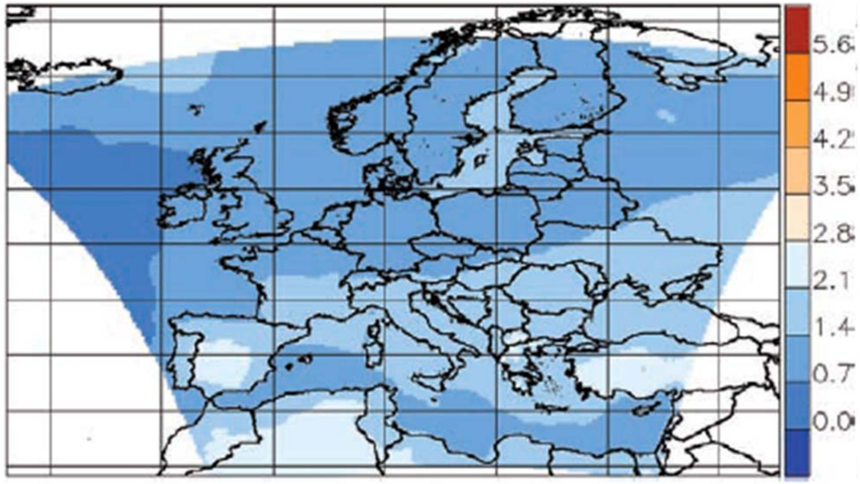


And the future?



Mean annual and summer temperature changes 2021-2050 versus 1961-1990, A1b scenario





- average of 50 climatic predictions - model: *ensemble mean* – RCM

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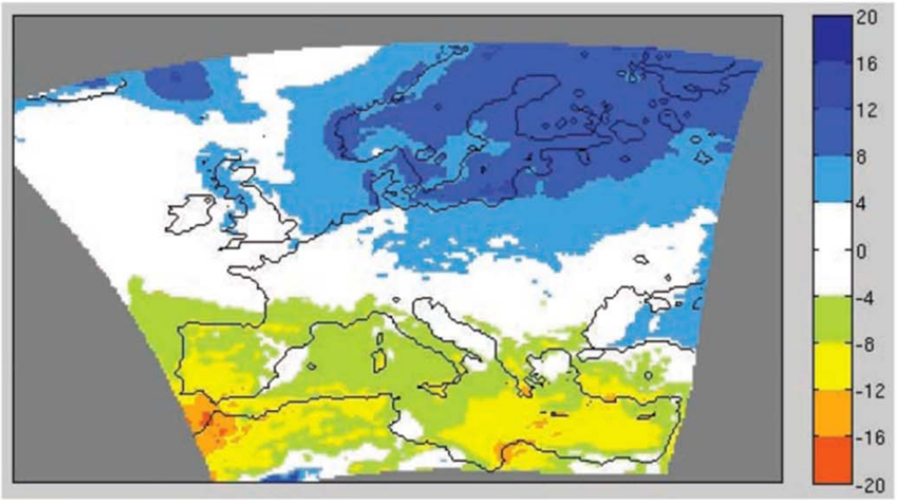
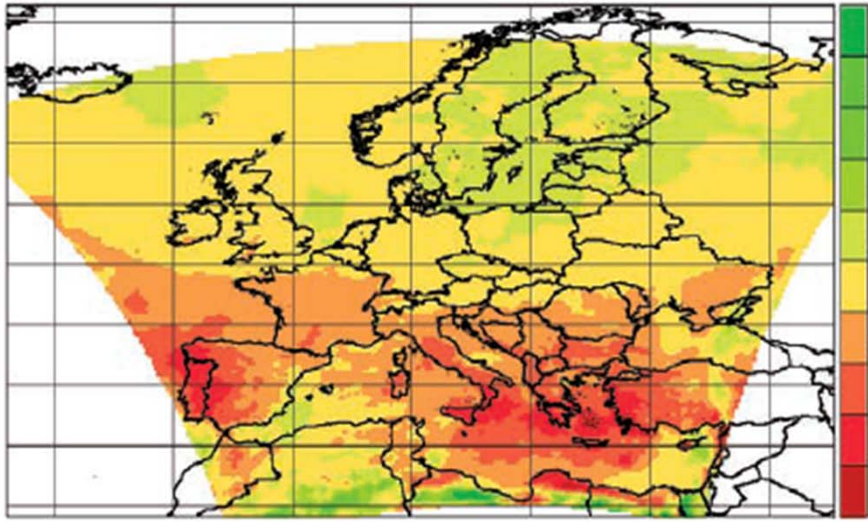
Total and summer rainfall changes
2021-2050 versus 1961-1990, A1b scenario





- average of 50 climatic predictions - model: *ensemble mean* – RCM

//ensembleseu.metoffice.com/docs/Ensembles_final_report_Nov09.pdf

Predicting SOC changes

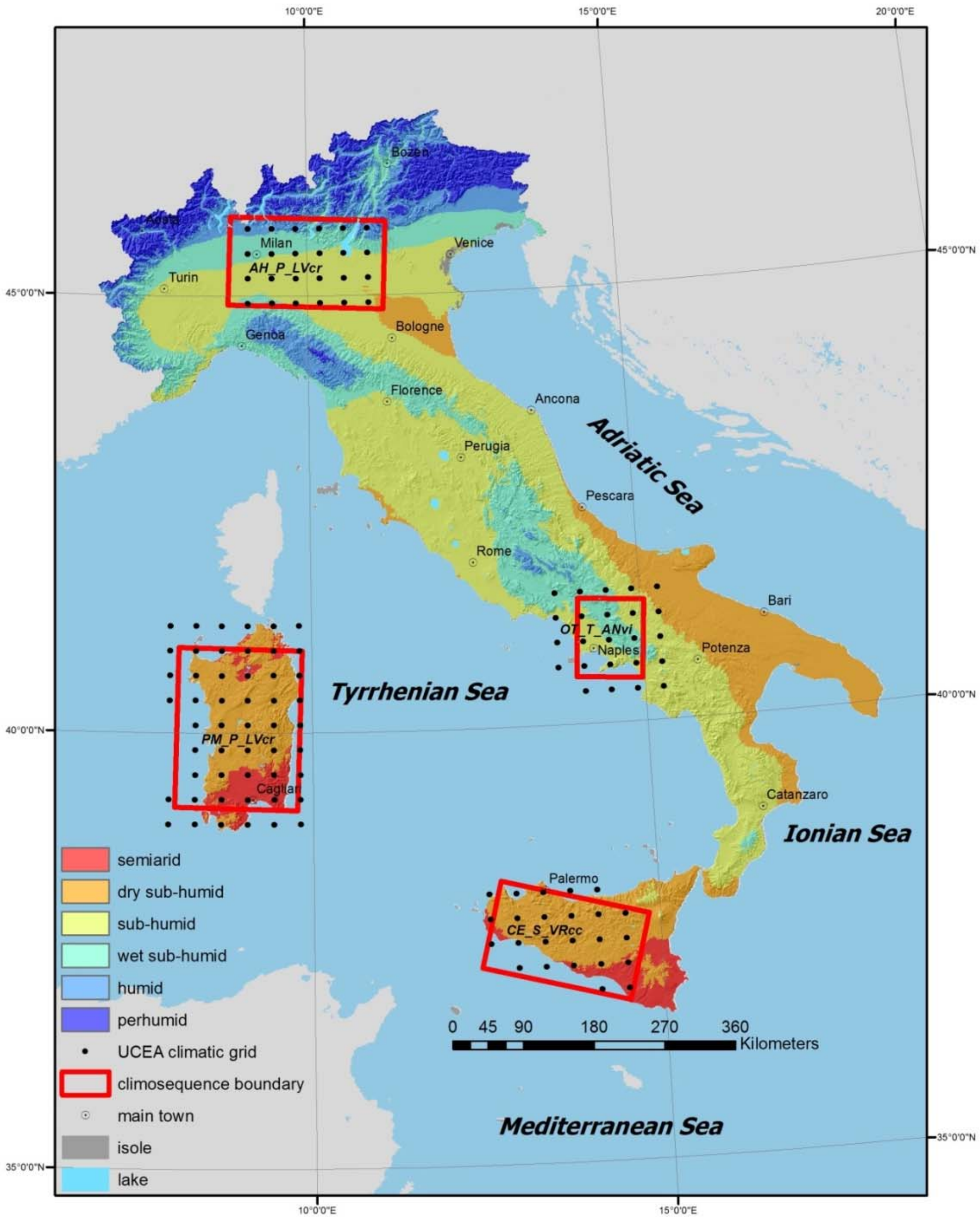
Strategies:

- Deterministic Modelling
- Empirical modelling
  - Space for time sampling (climosequences)

Materials and methods

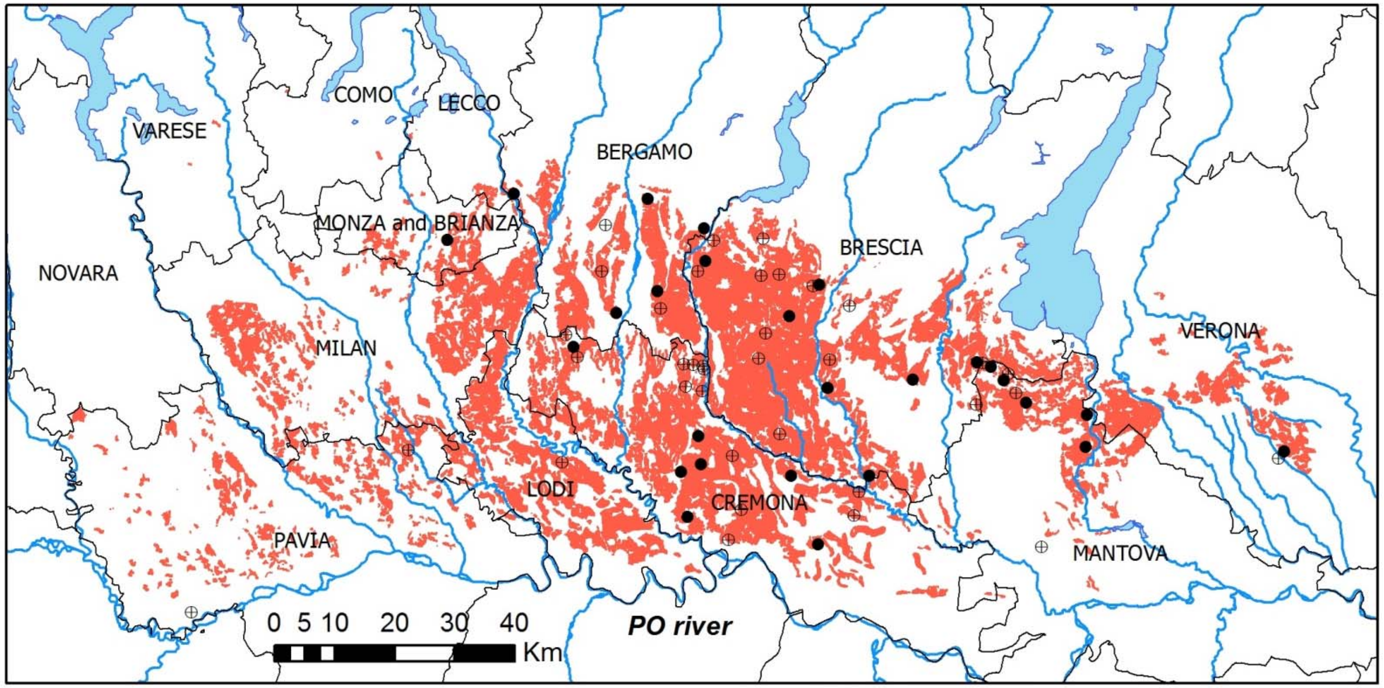
- ►Climatic parameters from the national grid (30x30 km),
  - ► downscaling to a 1 km grid
  - ► three reference long-term climates:
    - ► past 1961-1990 (t1)
    - ► present 1981-2010 (t2)
    - ► future 2021-2050 (t3)

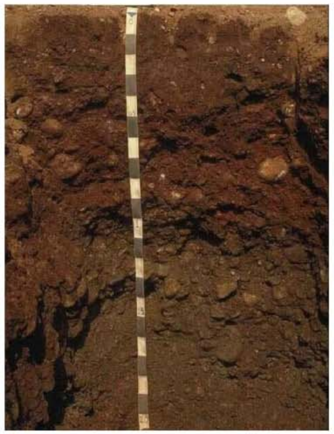
Materials and methods



- ►114 soils sampled along climatic gradients
- ► 3-4 replications
- ►59 legacy sites, surveyed in the years 1960-2000, resampled and analysed in 2011 + 55 new sites
- ► Land use permanence along years checked by remote sensing analysis

Po valley





plots

- ⊕ not resampled
- • resampled
- AH_P_LVcr
- province
- rivers
- lakes

Cropping system

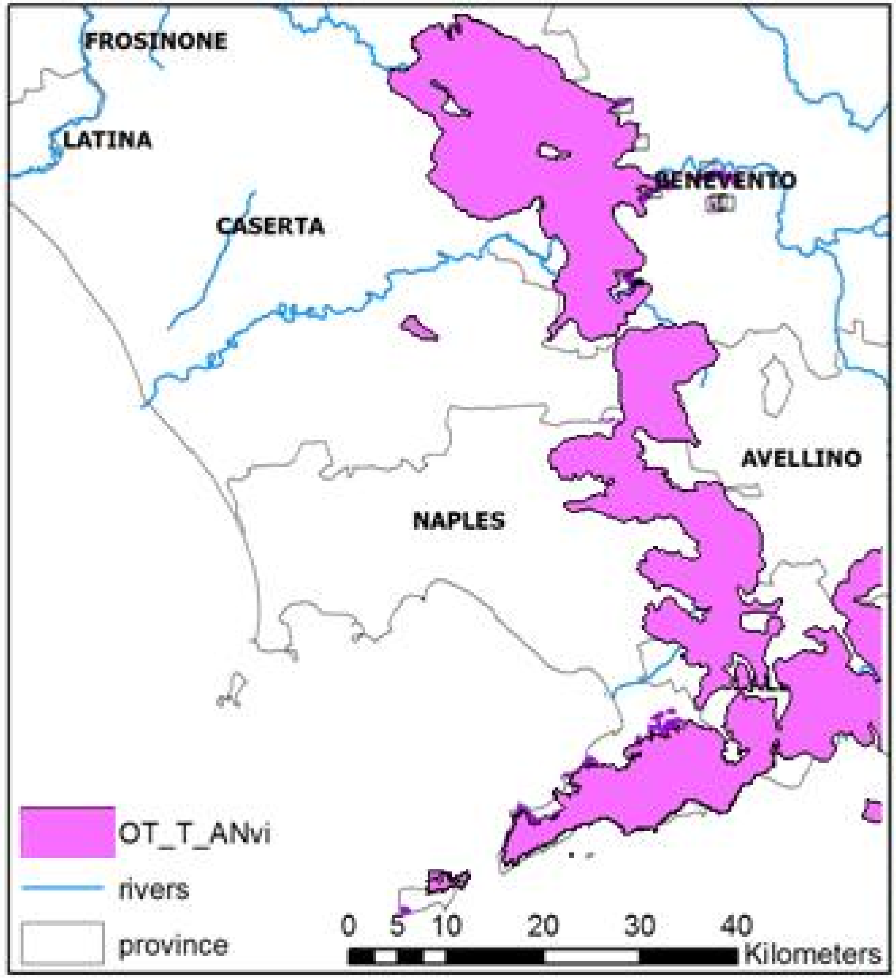
row crops and forage rotation

Soil

Chromic Luvisol, loam

resampled	total
24	32

Campania



Cropping system

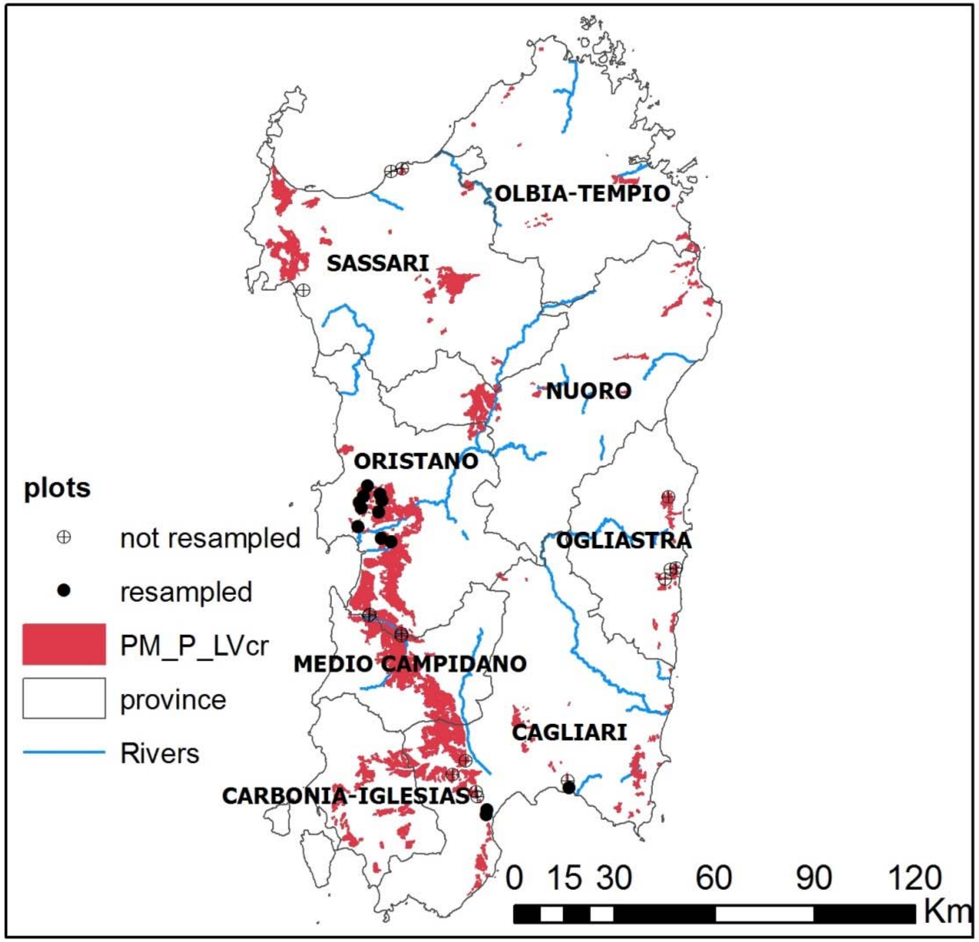
olive tree groves

Soil

Vitric Andosol, medial

resampled	total
7	28

Sardinia



Cropping system

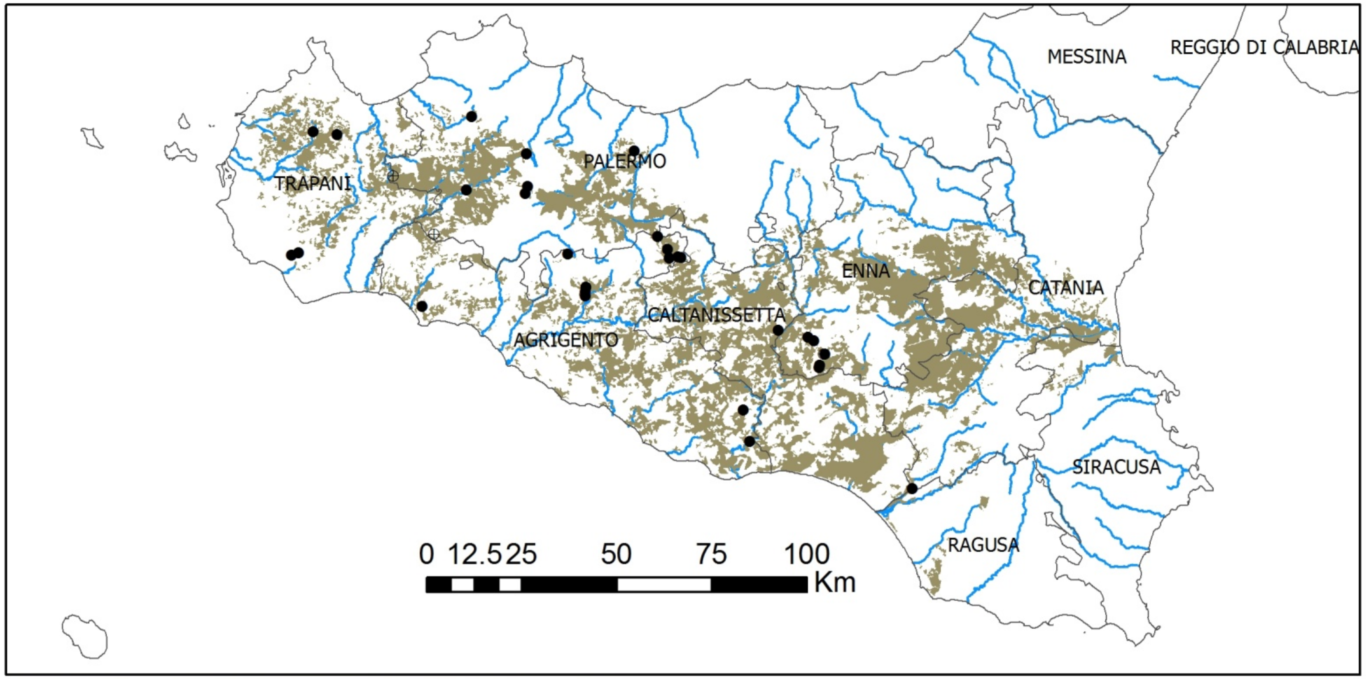
permanent meadows

Soil

Chromic Luvisol, sandy loam

resampled	total
14	30

Sicily



plots
not resampled
resampled
CE_S_VRcc
province
Rivers

Cropping system

cereals

Soil

Calcic Vertisol, clay

resampled	total
18	34

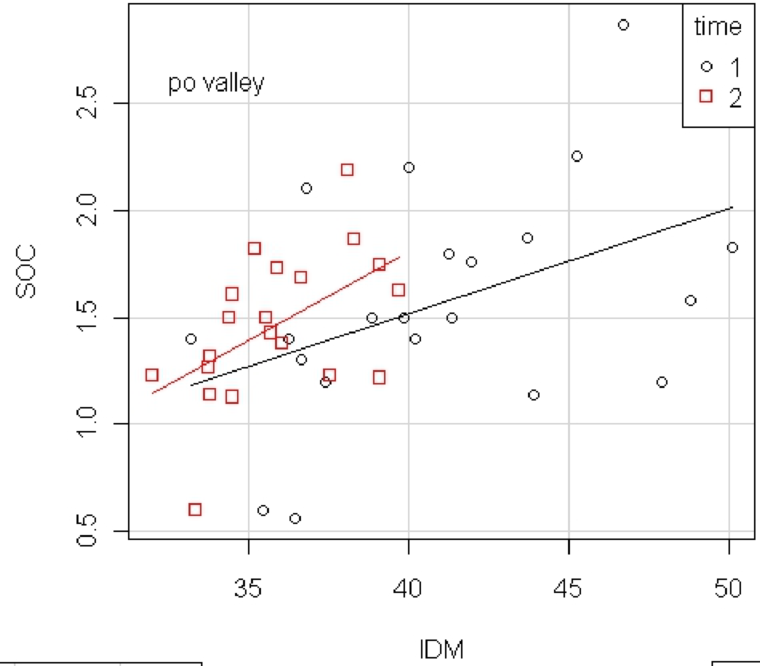
Organic carbon and climatic indices (1961-2010)

ZONE	MAP		MAT		IDM		AI	
	cor	p-value	cor	p-value	cor	p-value	cor	p-value
Po valley	0.42	$2*10^{-6}$	-0.34	$1*10^{-4}$	0.4	$5*10^{-6}$	0.38	$1*10^{-5}$
Campania	0.26	0.01	-0.3	0.004	0.4	$2*10^{-4}$	0.3	0.004
Sardinia	0.31	0.002	-0.1	0.3	0.28	0.005	0.3	0.003
Sicily	0.47	$2*10^{-8}$	-0.37	$1*10^{-5}$	0.46	$3*10^{-8}$	0.42	$4*10^{-7}$

IDM De Martonne = [MAP] / [MAT+10]

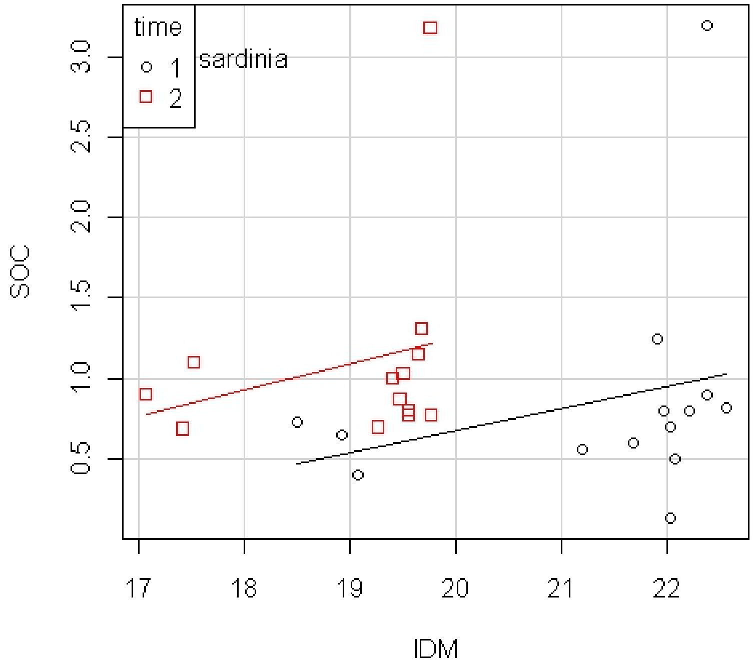
AI FAO UNEP= [MAP] / [$ETO_{PENMAN-MONTEITH}$]

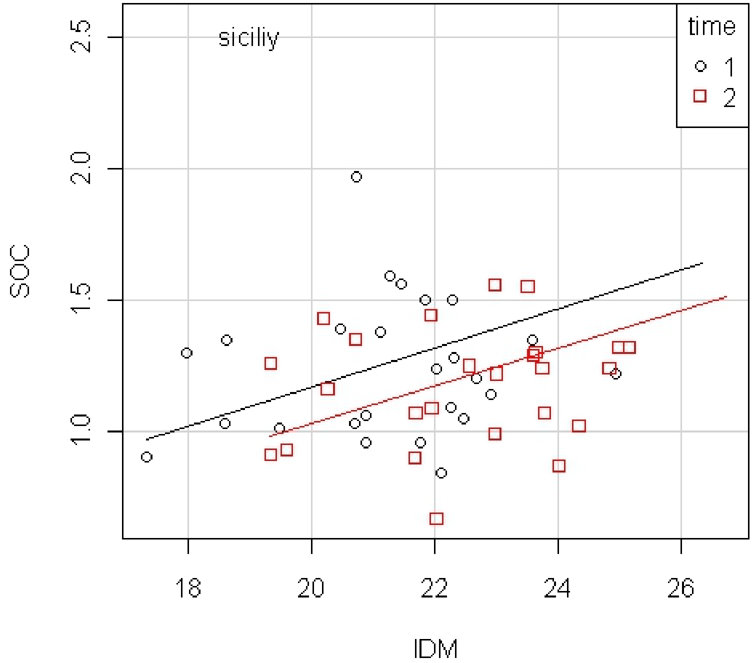
validation in time: SOC vs IDM in t1 and t2



anova test

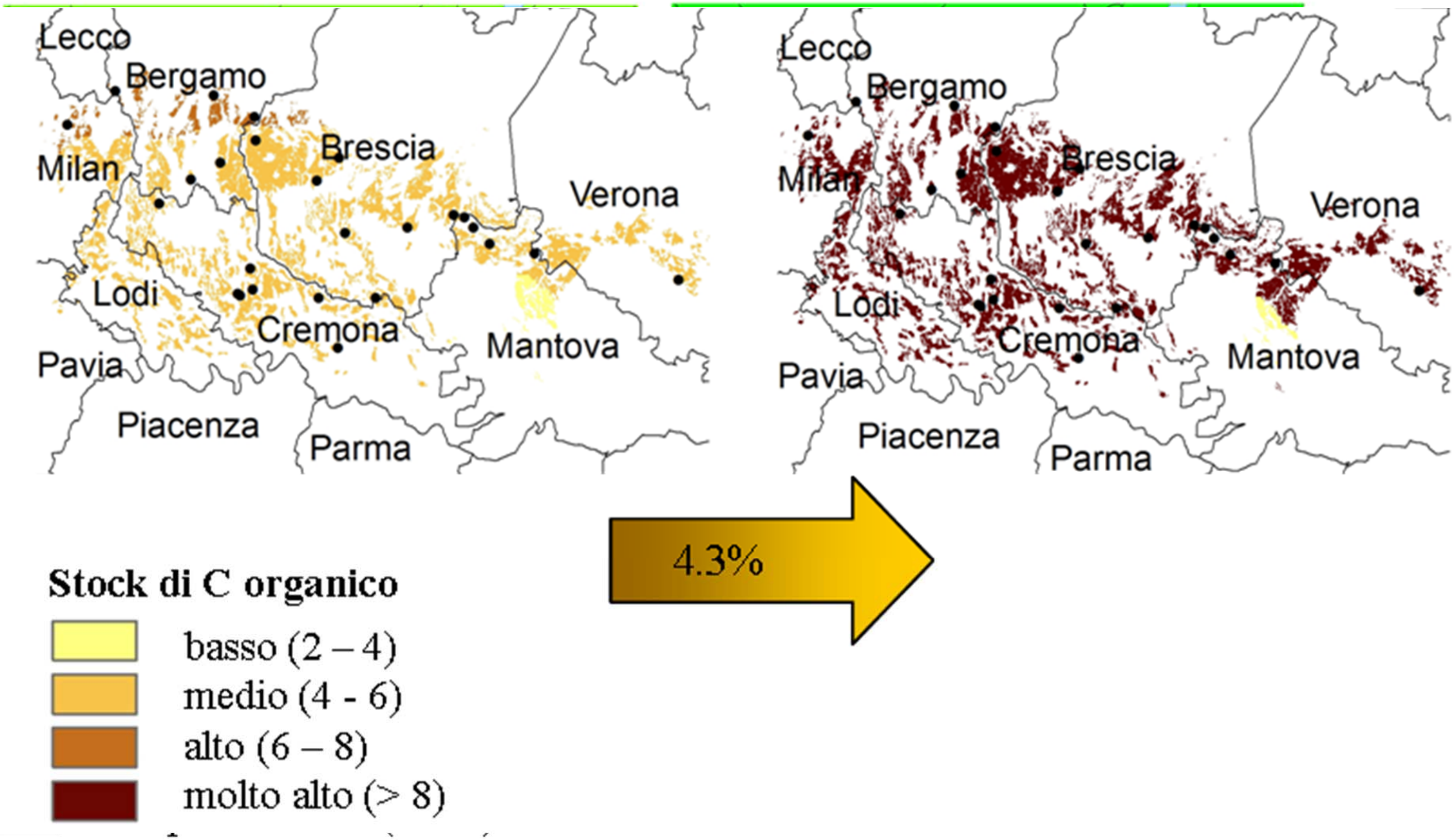
(SOC-IDM)*t	Pr (>F)
po	0.47
sar	0.85
sic	0.96





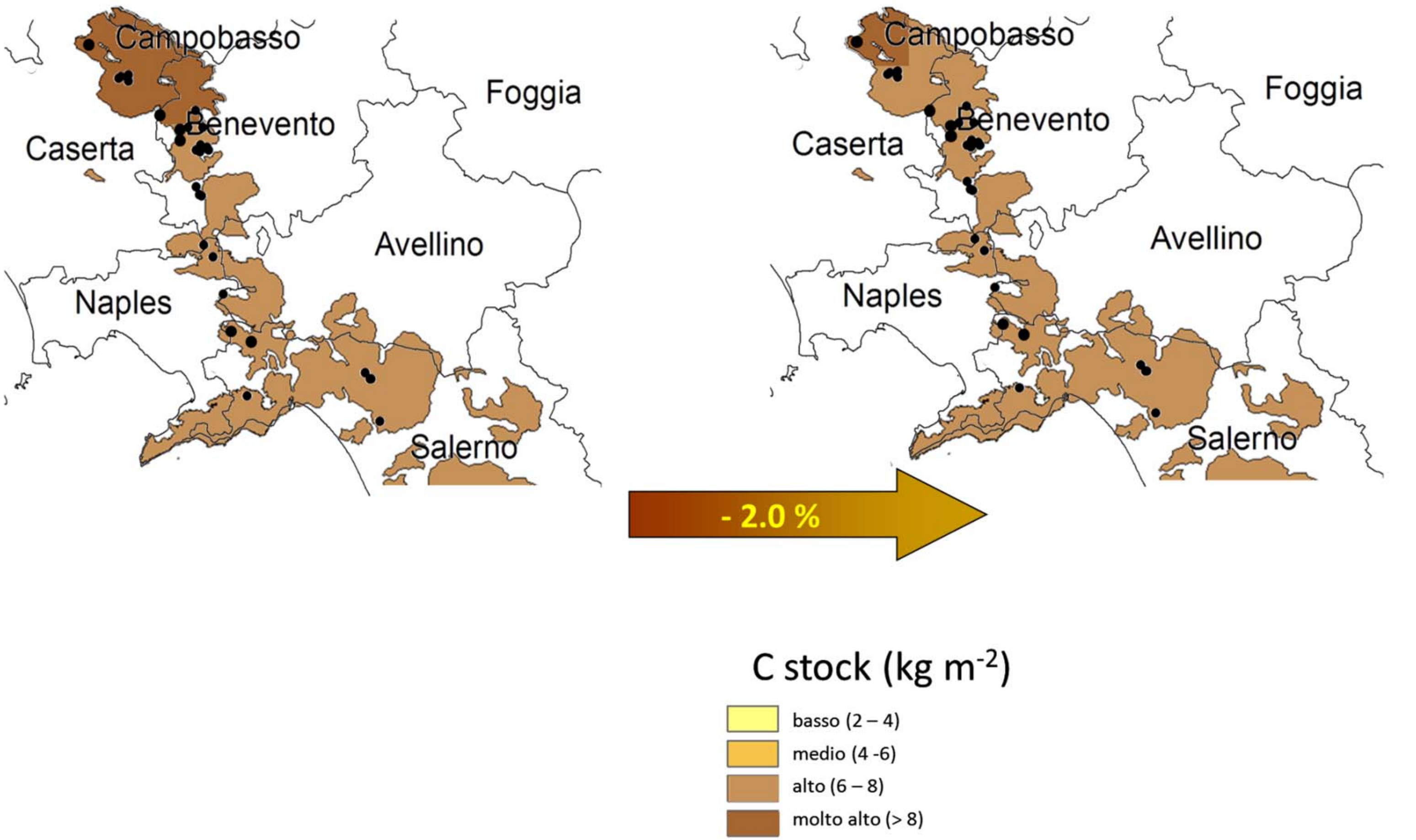
Row crops cropping system on Chromic Luvisols 1981-2010 vs 2021-2050

SOC = 0,050IDM – 0,984 (gdl = 22; p<0,01).

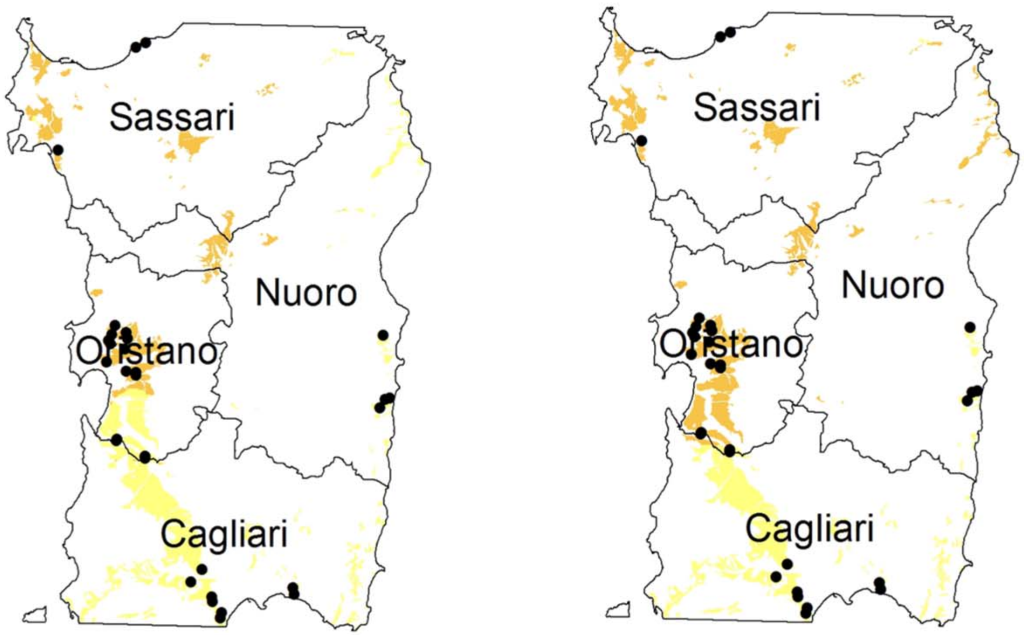


Olive tree cropping system on Vitric Andosols 1981-2010 vs2021-2050

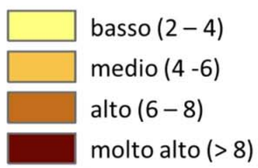
SOC = 0,063IDM – 0,203 (gdl = 26; p<0,05).



Meadows cropping system on Chromic Luvisols 1981-2010 vs 2021-2050

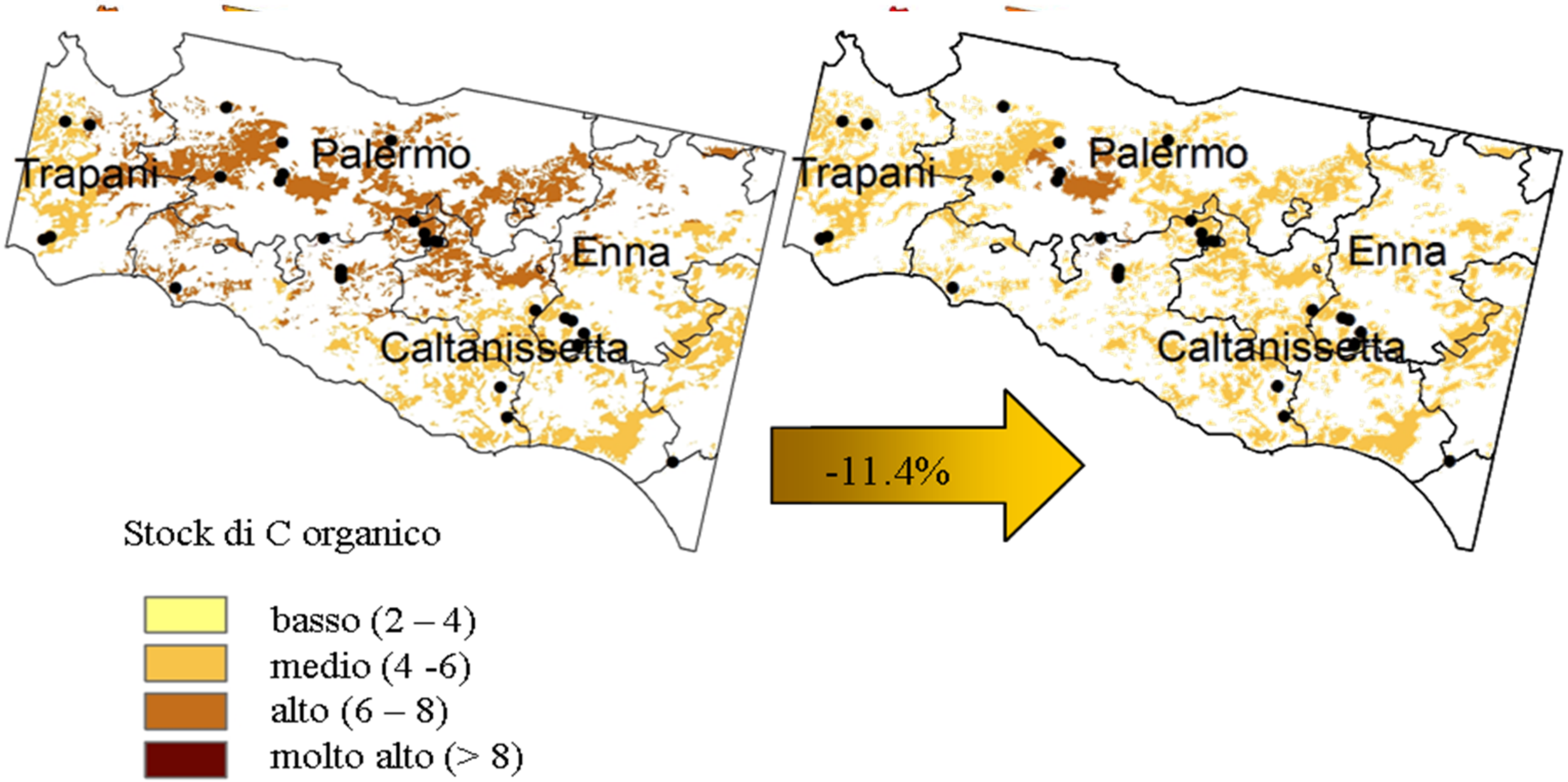


SOC = 0,050I DM+ 0,053 (gdl = 26; p<0,01).



Cereals cropping system on Calcic Vertisols
1981-2010 vs 2021-2050

SOC = 0,064IDM – 0,242 (gdl = 32; p<0,001).



Conclusions (2)

1. Land use and management play a larger role than climate on SOC variations, but
2. Climate change already influenced and is going to further affect SOC stock
3. Meadows is the most sensitive land use to both negative and positive changes, followed by croplands and forestlands
4. Future SOC changes will be different according to local soils and cropping systems
5. Interactions between climate change and management of the cropping systems will be relevant in determining future SOC stocks (e.g. conservation agriculture, precision agriculture, and water management)

Thank you for your attention!

Acknowledgments:
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