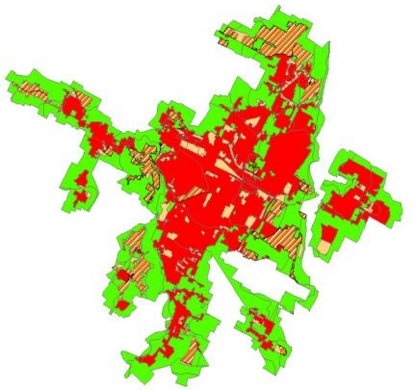
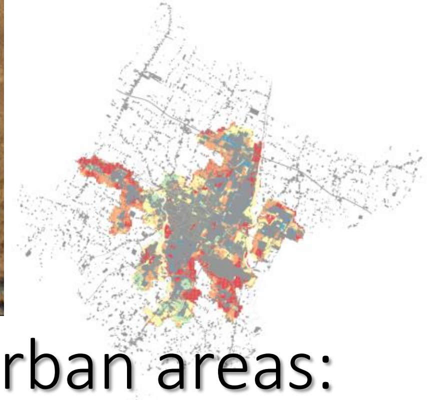
Maria Costanza Calzolari

Assessing and mapping soil ecosystem services in urban and peri-urban areas

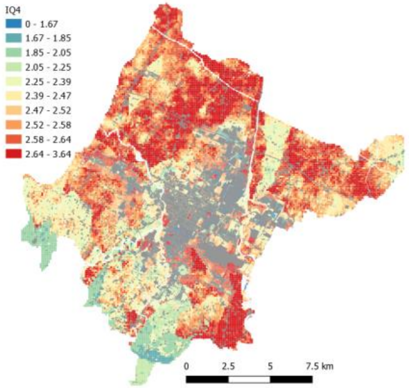
100 years of SOIL SCIENCE past achievements and future challenges





Assessing and mapping soil ecosystem services in urban and peri-urban areas:

providing support tools for urban planning in the Municipality of Forlì



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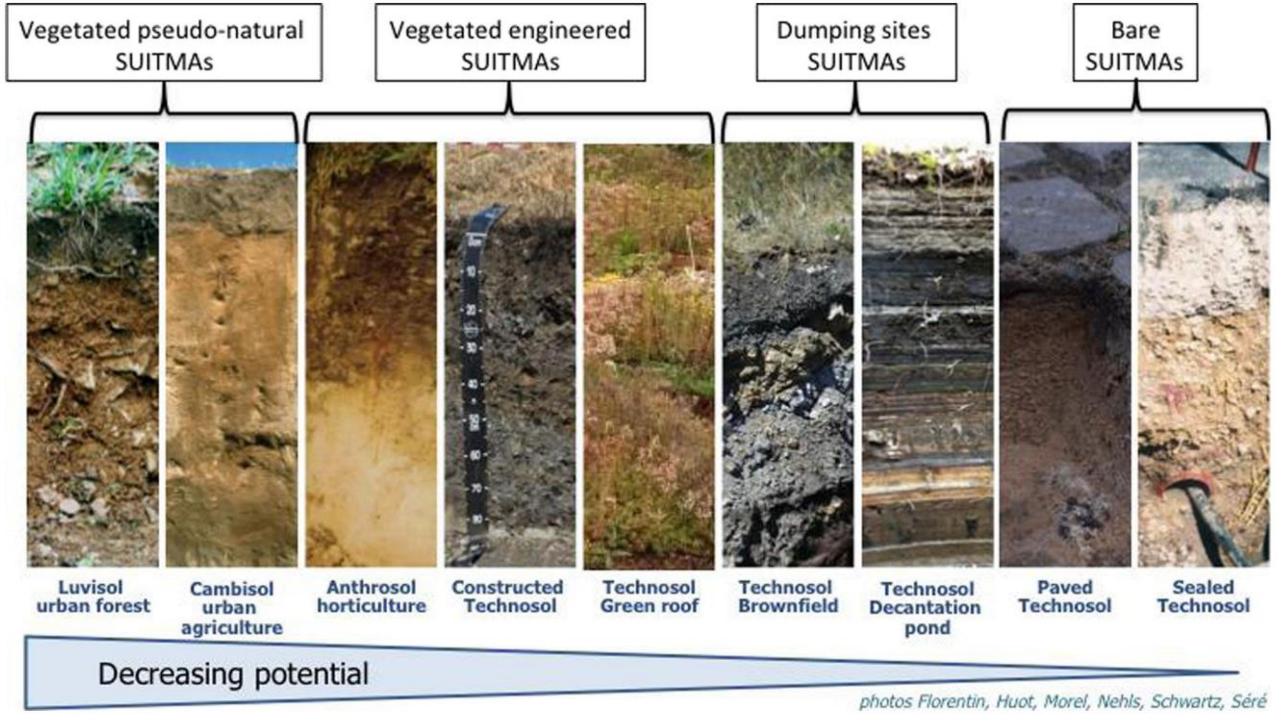
CONTENTS

- Urban soils: characteristics and ecosystem services
- Mapping and assessing SESs of urban soils
- Forlì municipality Emilia-Romagna (NE Italy)

Urban soils



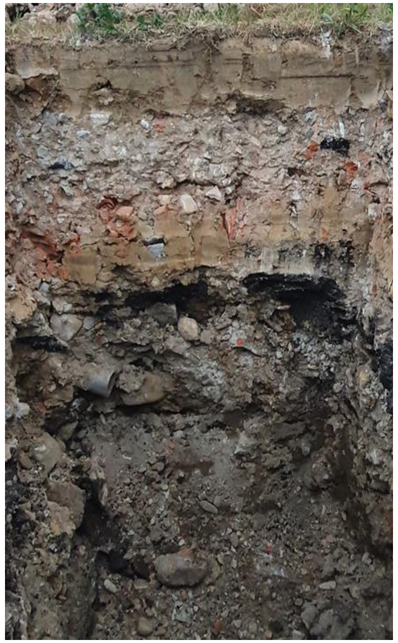
•https://doi.org/10.1080/00380768.2015.1054982

Urban soils are all soils located within urban areas.

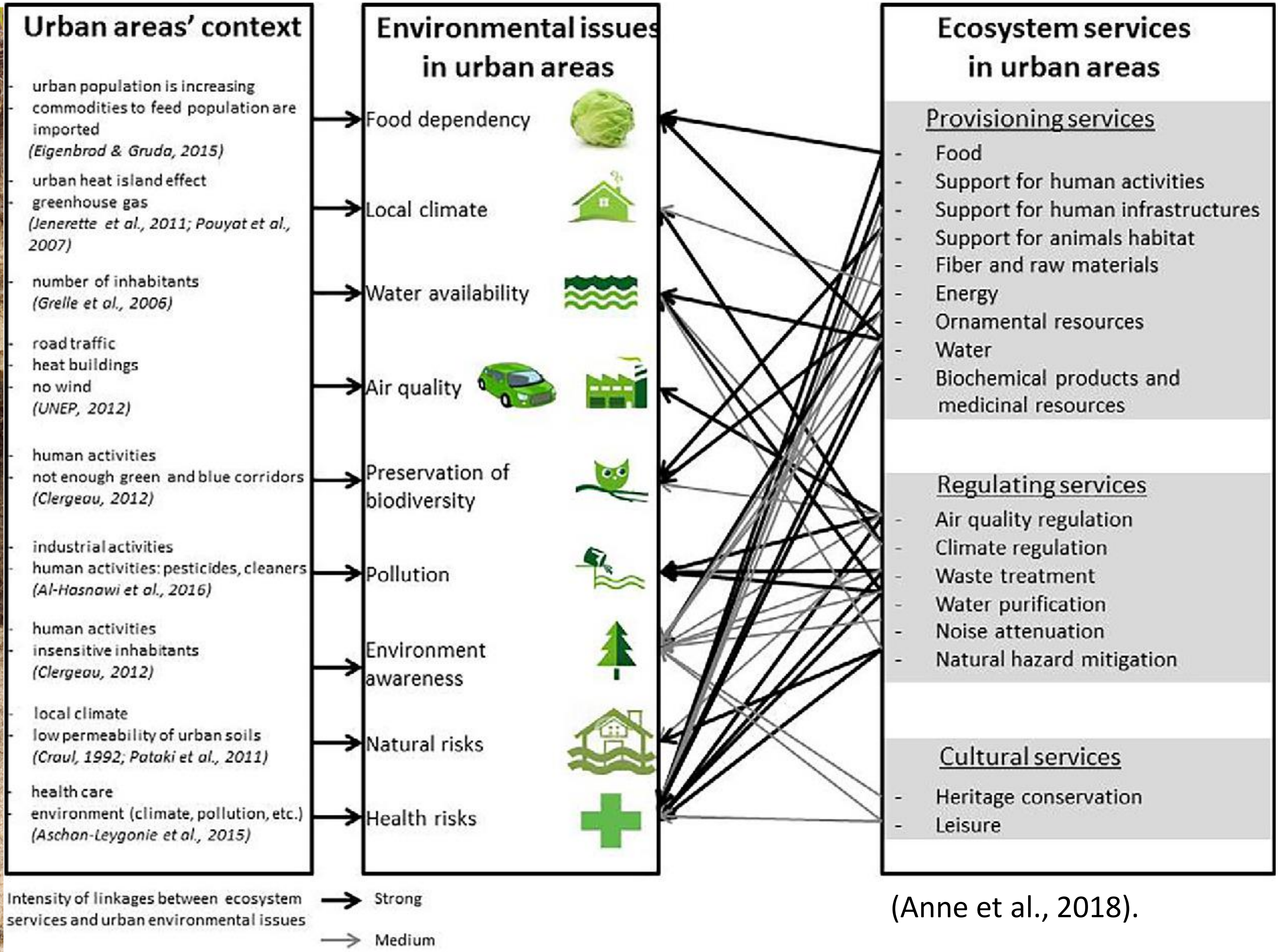
Urban soils are included within **SUITMA** (**S**oils of **U**rban, **I**ndustrial, **T**raffic, **M**ining and **M**ilitary **A**reas), defined as soils strongly modified by human activities with drastic changes in composition and functions, though in urban areas, they can include both highly-transformed soils and pseudo-natural soils (Morel et al., 2015).

Urban soils are characterized by:

- ❑ An extreme vertical and horizontal variability
- ❑ A variable degree of anthropic disturbance
- ❑ The presence of allochthonous (soil) material and/or human artifact
- ❑ A variable amount of diverse contaminants
- ❑ A variable degree of surface sealing (0 to 100%)



Ecosystem services of urban soils



(Anne et al., 2018).

Links between ecosystem services provided by urban soils and major environmetal issues in urban areas

As with nonurban soils, urban soils provide ecosystem services. Because of the close proximity of urban soils with dense human populations, the importance of ecosystem services is especially magnified for (managed) **regulating services** and (managed) cultural services

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Mapping and assessing the SESs of urban soils

Guidelines for assessing soil ecosystem services in urban environment

Prior knowledge of soils, of their properties and distribution in space is required to assess and eventually map their ecosystem services.

Three approaches are possible depending on resources and data availability

1. Ad hoc soil survey: sampling -> analyses -> mapping -> ESs assessment
2. Use existing soil data base and maps (vector format): benchmark soil profiles and analytical data -> ESs assessment
3. Use existing soil properties/functions maps (raster format) -> ESs assessment

In all cases soil data are at the base of the assessment and these are used to build indicators of ecosystem service potential provision.

In these last years a great effort has been devoted to SESs reliable indicators (e.g. Faber et al., 2022) and several evaluation schemes tailored on soils are becoming available stemming from EU funded projects (e.g. RECARE, EJP SERENA).

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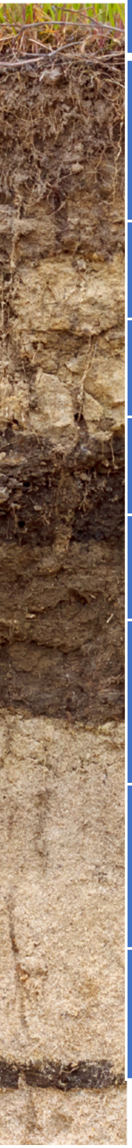
Mapping and assessing the SESs of urban soils



Ecosystem Services[a]	Code CICES 5.1 [b]	Soil contribution to ES[c]	Soil functions[d]	Indicators	Input data	Code
Regulating	2.2.1.1 2.3.3.2	Nutrients/pollutants retention and release Filtering capacity (potential)	Storage, filtering and transformation of nutrients and water	CEC Soil pH	C org % Clay % pH Skel %	BUF
Regulating	2.1.1.2 2.3.3.2	Carbon stock (potential)	Carbon pool	Actual C sequestration	C org % Bulk density	CST
Regulating	2.2.1.1 2.2.1.3	Reduction of soil losses due to water erosion	Support to vegetation	Actual erosion	RUSLE factors C, K, LS, R	ERSPRO
Provisioning	1.1.1.1	Food provision (potential)	Biomass production (food)	Soil cability map	LCC e integrades	PRO
Provisioning	1.1.1.x 1.1.5.x	Biomass provision (potential)	Biomass production	NDVI, mean 2015-2020	NDVI (Landsat 8)	BIOMASS
Regulating	2.2.1.3	Water regulation/runoff and flood control (potential)	Riserva, filtraggio e trasformazione delle sostanze nutritive e dell’acqua	Infiltration capacity	Ksat (mm/h) Psi_e (cm)	WAR
Regulating (Provisioning)	2.2.1.3 (4.2.2.2)	Water regulation – water storage (potential)	Riserva, filtraggio e trasformazione delle sostanze nutritive e dell’acqua	Water content at field capacity	Field capacity (-33 kPa)	WAS
Regulating	2.2.2.3	Habitat for soil organisms	Biodiversity pool	Habitat (potential) for soil organisms	QBS-ar Covariates DSM	BIO

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Mapping and assessing the SESs of urban soils

SES	Input data	Indicators calculation
BUF	CEC (cmolc/kg) as function of OC (%) and clay (%) CEC = 6.332 +0.404 clay + 1.690 OC (R^2 = 0.75) pH Coarse fragments content, sk (%) Shallow water table depth, WT (cm)	BUF_{0-1} = Log CSC (pH; sk)$_{0-1}$ With pH<6.5 reduction by 0.25 or 0.5 depending on CEC and by 0.25 for skel. >30% With shallow water table depth (WT) < 30 cm BUF_{0-1} = Log CSC (pH; sk)$_{0-1}$*WT/30
CST	Organi carbon, OC (%) Bulk density, BD (Mg m^{-3})	CST_{0-1} = log [OC * BD * (1-SK)]$_{0-1}$
ERSPRO	Potential soil erosion (Mg ha^{-1} y^{-1}) Actual soil erosion(Mg ha^{-1} y^{-1})	Standardization (0-1) Log10 (Potential erosion – actual erosion)
PRO	Capability class and intergrades	LCC class scaling (0-1)
BIOMASS	NDVI (Normaized Difference Vegetation Index)	Standardization (0-1) NDVI (mean of 2015-2020 median values)
WAR	Saturated hydraulic conductivity, Ksat (mmh^{-1}) Air entry potential PSIe (cm)	$WAR_{0-1} = logKsat_{0-1} - PSIe_{0-1}$
WAS	Field capacity (-33 kPa), WCFC (vol/vol) Average shallow water table depth, WT (cm) Sk, coarse fragments (Ø >2 mm, vol/vol)	WAS_{0-1} = (WC_{FC} * 1−sk)$_{0-1}$ WT depth> 100 cm, and WAS_{0-1} = (WC_{FC} * 1-sk)*WT/100 with WT depth <100 cm
BIO	QBS_{ar} Covariates for Digital Soil Mapping	DSM approach (Quantile Random Forest)

- 0.0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1.0

All indicators, with the exception of PRO, are rescaled to the 0-1 interval with the following:

$$X_{i\ 0\text{-}1} = (X_i - X_{min})/(X_{max} - X_{min})$$

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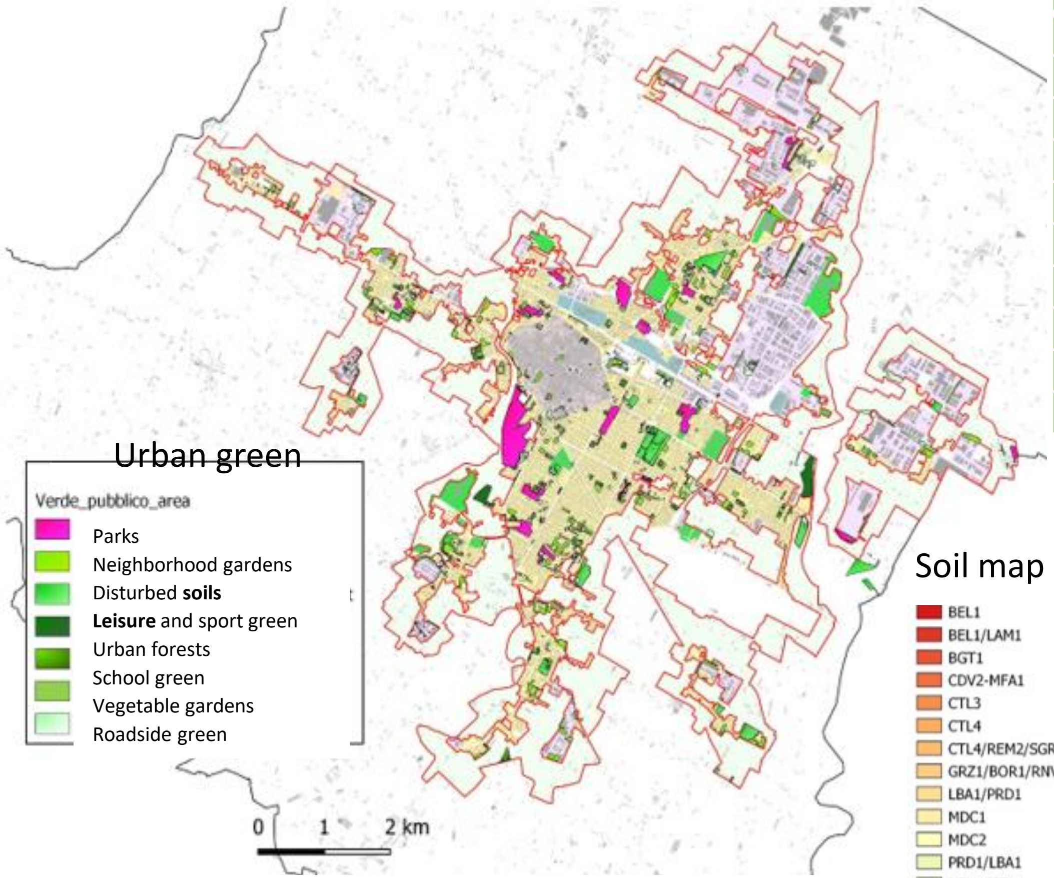
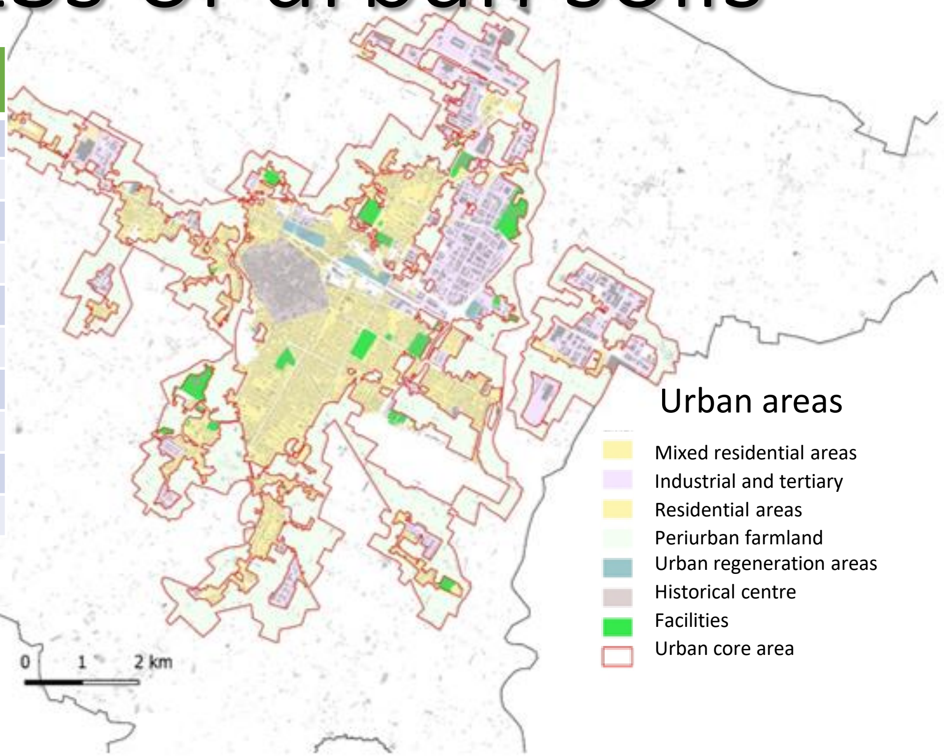
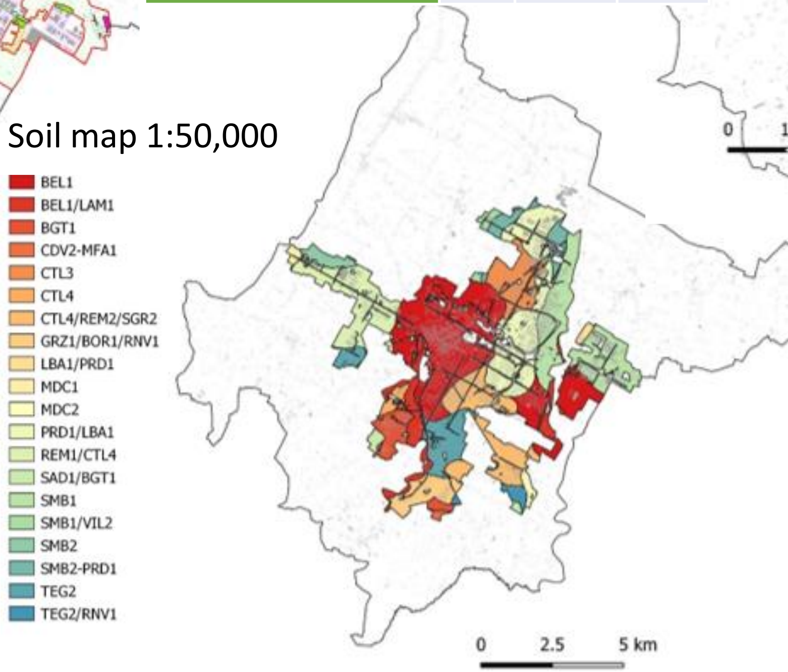
Mapping and assessing the SESs of urban soils

Urban green typologies	N	Area ha	%
Neighborhood gardens	208	81.54	27.1%
Parks	19	76.28	25.4%
Roadside green	192	45.04	15.0%
School green	76	19.28	6.4%
Vegetable gardens	22	5.21	1.7%
Urban forests	13	14.51	4.8%
Sport and leisure green	38	58.77	19.5%
Sub total	568	300.65	100.0%
Periurban farmland		2775.66	
Total		3076.31	







Urban areas	Area, ha	%
Periurban agricultural land	2775.7	50.9
Mixed residential area	1470.1	27.0
Industrial and tertiary urban areas	855.4	15.7
Residential areas	7.5	0.1
Urban regeneration areas	50.0	0.9
Historical centre	156.3	2.9
Facilities	137.1	2.5
Total	5452.0	100.0

Samples were located in urban green areas after the identification of preliminary urban pedolandscapes based on soil map units and urban area typologies

Municipality of Forlì: Microclimate vulnerability and ecosystem services of urban soils functional to the general urban plan

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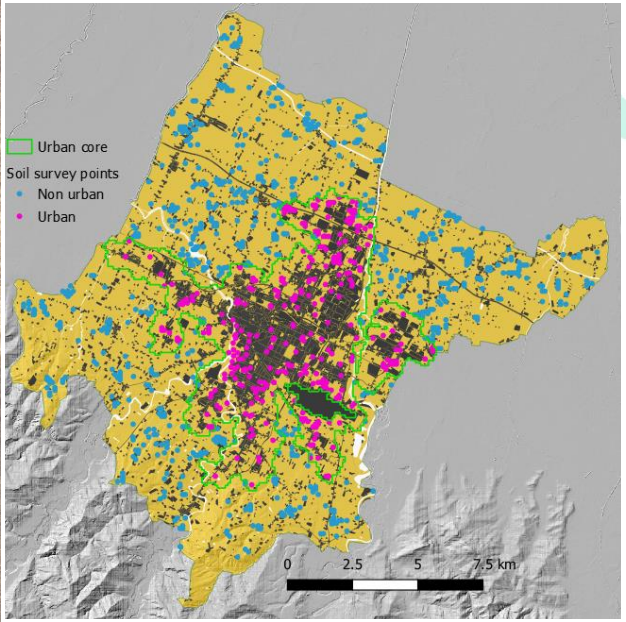
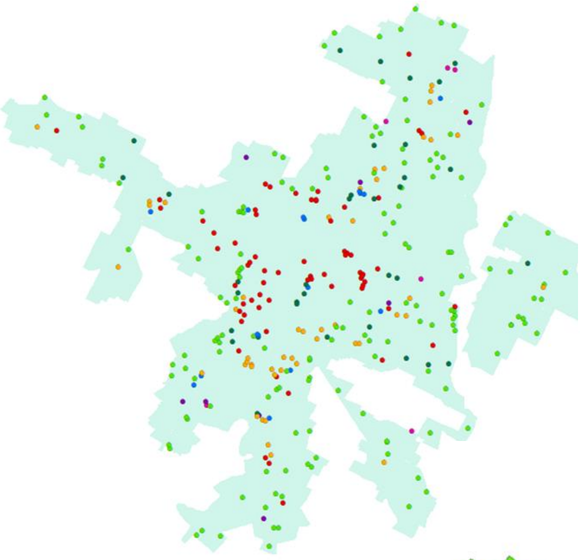
Mapping and assessing the SESs of urban soils

Assessing and mapping SESs in urban environment: *ad hoc* survey of urban soils



Area: 22836 ha (228,36 km^2)

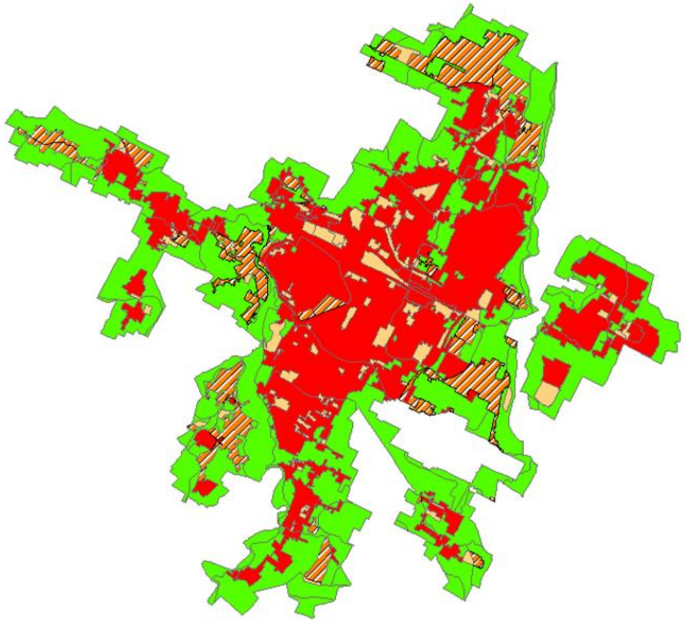
- Existing data (N = 98)
- *Ad hoc* survey (N = 248)



- Undisturbed
- A(p) *in situ*, disturbed
- Allochthonous soil material + buried original soil
- Mixing of horiginal soil horizons
- Allochthonous soil material
- Disturbed after survey and sampling
- Sealed

Soil disturbance	ha	%
Undisturbed soils	2771.43	48.70
Disturbed soils	274.37	4.82
Urbanized/disturbed soils	586.43	10.31
Urbanised	2058.42	36.17
Total	5690.65	100

- Undisturbed soils
- Disturbed soils
- Urbanised/disturbed soils
- Urbanised



Municipality of Forlì

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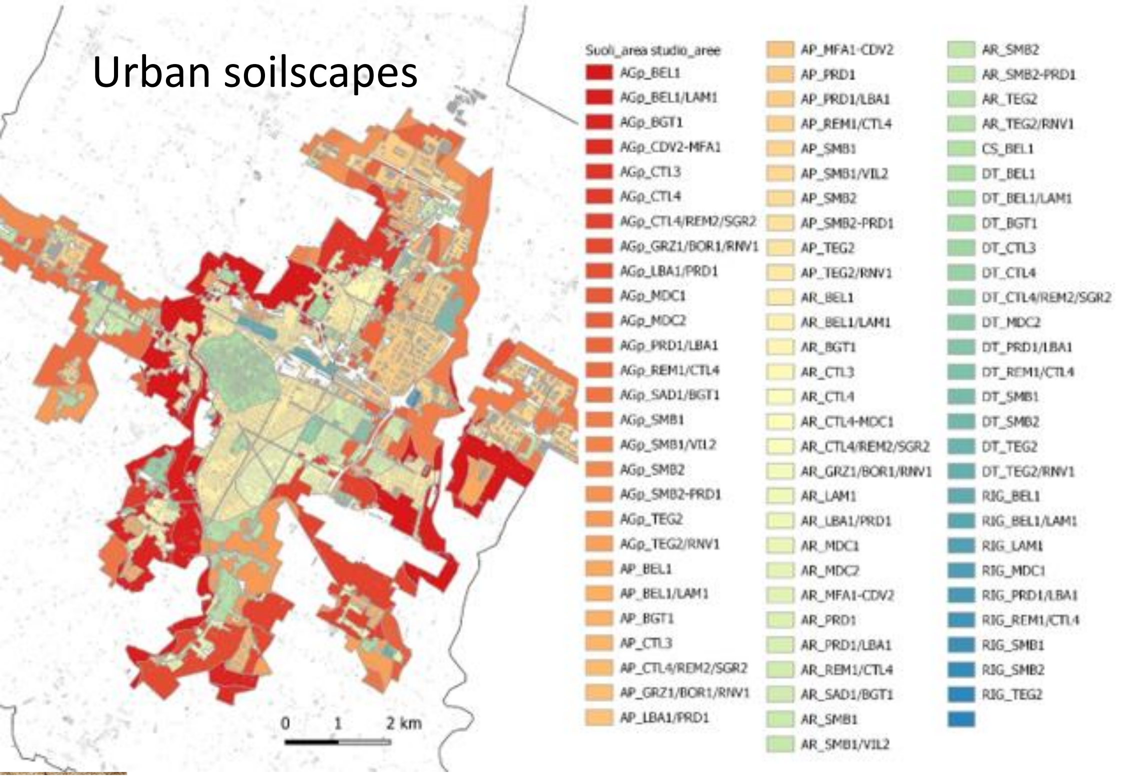
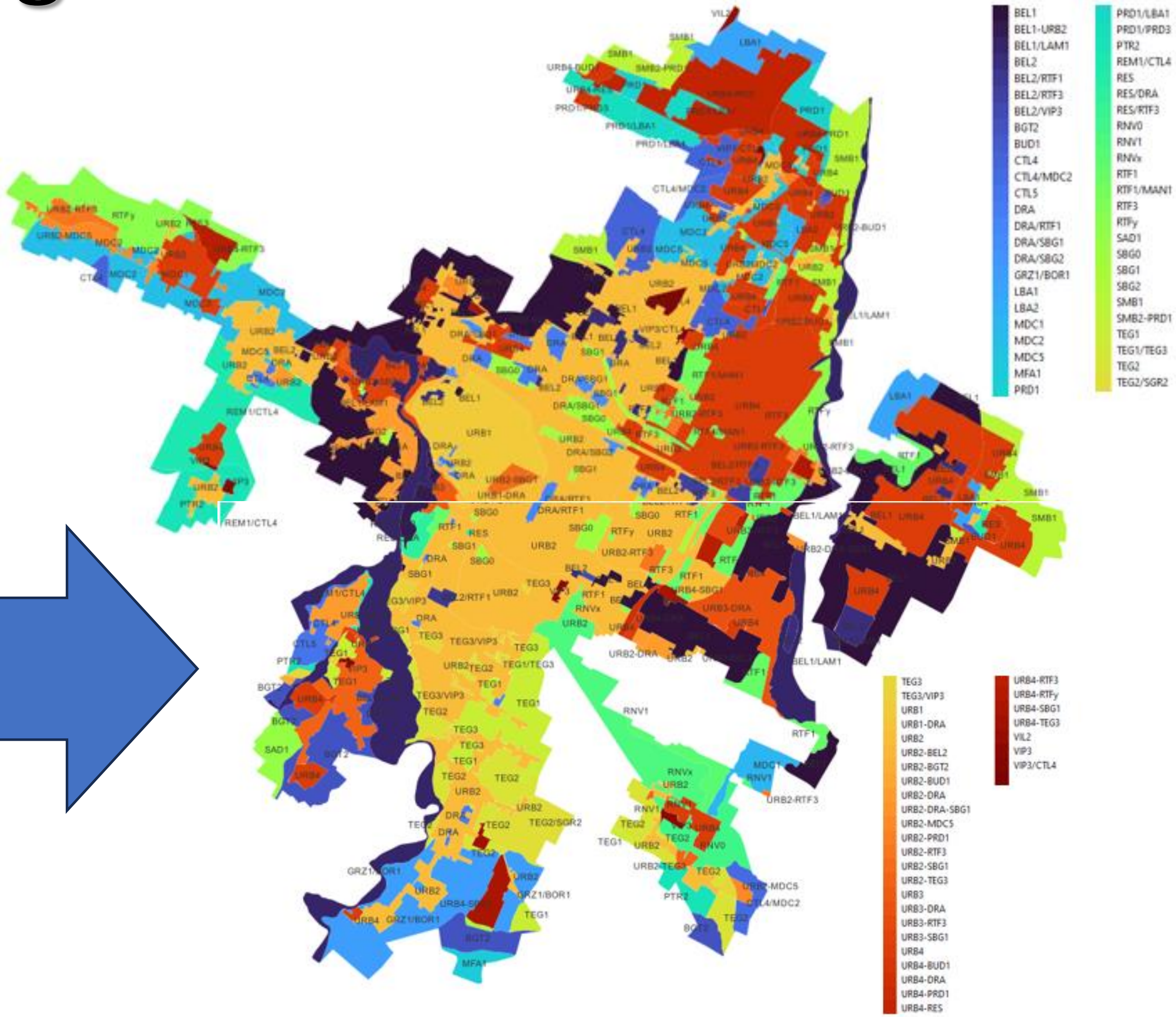
Mapping and assessing the SESs of urban soils

Urban soilscapes





As a results 83 urban soilscapes were identified, proportionally allocating samples in the different green areas of the most relevant ones. The description of soil features from hauger holes and profiles and the analysis of soil samples allowed to define the urban soil units and to draw them on a map

Urban soils map 1:10,000
79 mapping units

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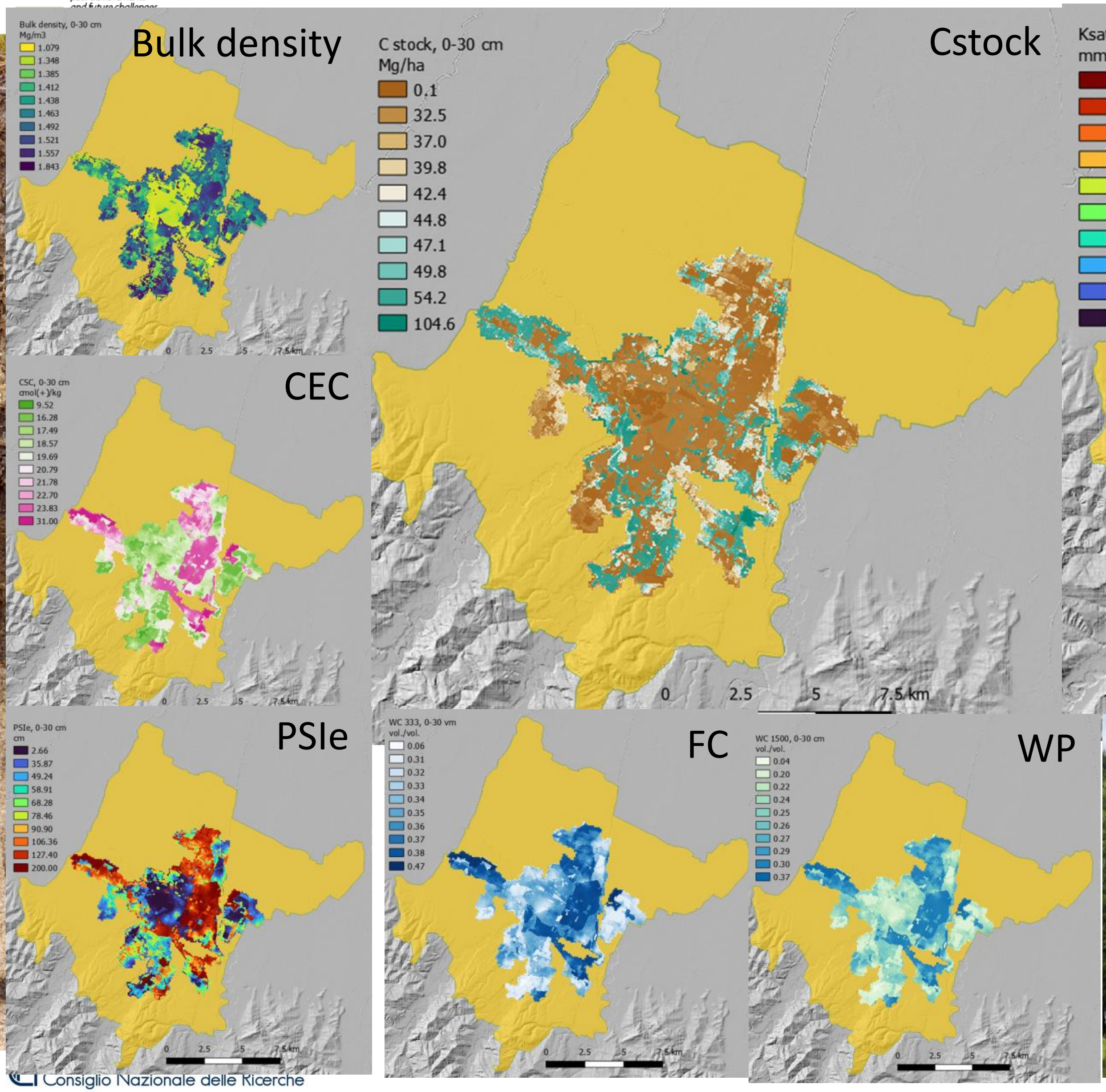

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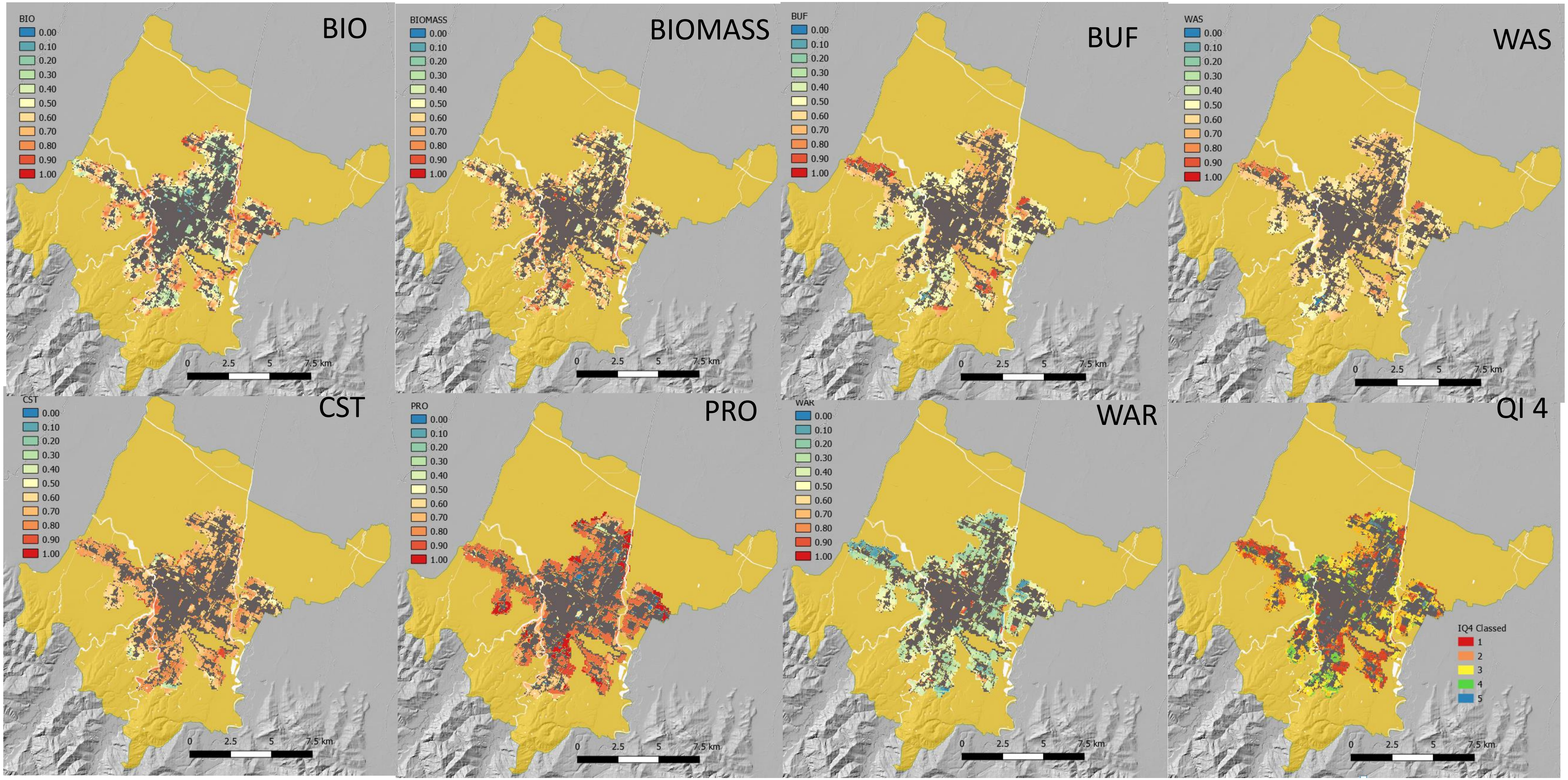

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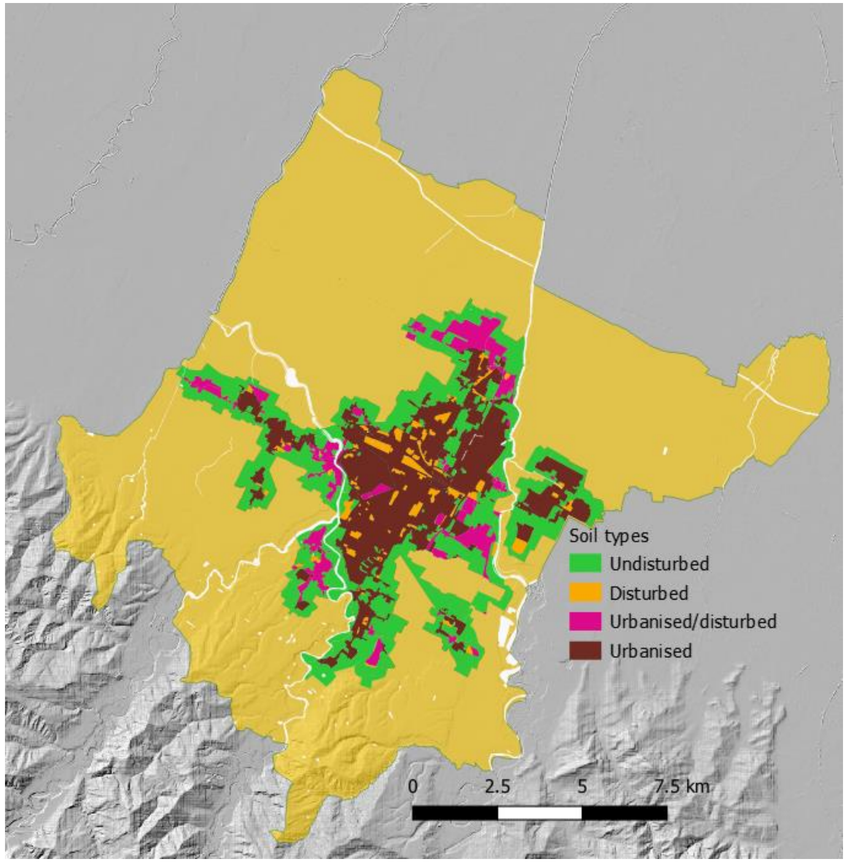
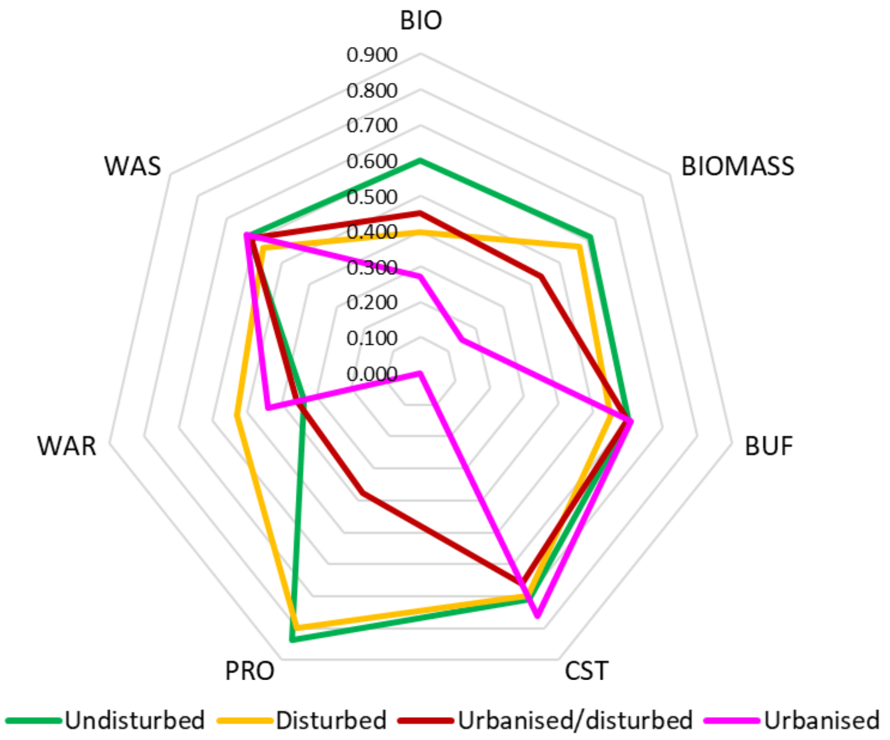
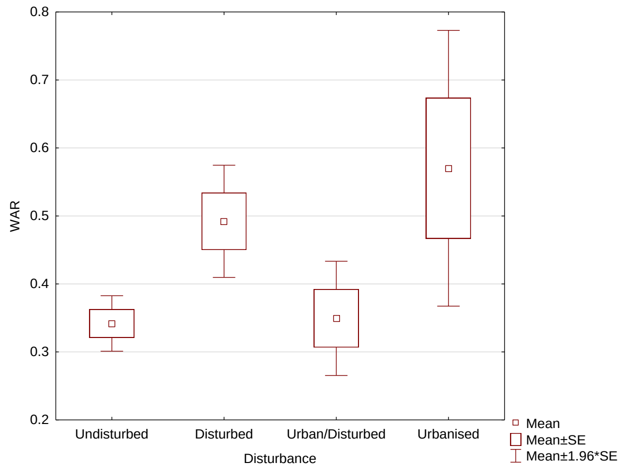
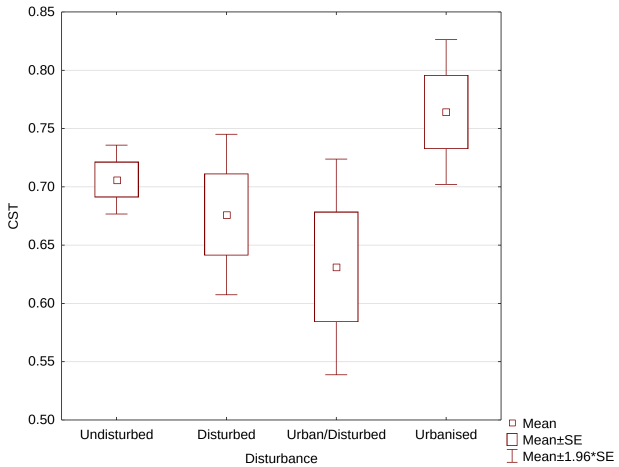
Mapping and assessing the SEsS of urban soils

Variable	Means	Std.Dev.	BIO	BIOMASS	BUF	CST	PRO	WAR	WAS
BIO	0.484	0.180	1.000	0.506	0.427	0.373	0.437	-0.102	0.421
BIOMASS	0.519	0.156	0.506	1.000	0.328	0.351	0.762	0.218	0.330
BUF	0.580	0.152	0.427	0.328	1.000	0.711	0.277	-0.342	0.890
CST	0.680	0.156	0.373	0.351	0.711	1.000	0.258	0.089	0.838
PRO	0.649	0.281	0.437	0.762	0.277	0.258	1.000	-0.001	0.305
WAR	0.395	0.183	-0.102	0.218	-0.342	0.089	-0.001	1.000	-0.217
WAS	0.587	0.137	0.421	0.330	0.890	0.838	0.305	-0.217	1.000









Ecosystem services of urban soils

In conclusion, the presented approach

- Allows to assess and compare the impact of soil sealing in term of reduction/loss of the ecosystem services provided by urban soils under different management options;
- Provides assessment tools to support land planning (i.e. maps) to the aim to reduce/compensate soil sealing taking explicitly into account local land resources and the functions of different soils (and at different scales)
- Highlights the multifunctional role played by soils in the urban environment and the relevance of the services provided to the citizens
- Urban soils have characteristics and properties similar to those of agricultural soils in the peri-urban areas, and result from less or more intense disturbance of in situ soils with or without addition of soil materials from nearby areas
- The inherent complexity of the urban soil environment requires *ad hoc* survey to properly quantify the contribution of soil ecosystem services and to identify potential disservices due to mis-use/-management

https://ambiente.regione.emilia-romagna.it/it/geologia/suoli/suoli-pianificazione/servizi-ecosistemici-del-suolo

https://www.sos4life.it/wp-content/uploads/Valutazione-dei-servizi-Ecosistemici-del-suolo.pdf

https://mappegis.regione.emilia-romagna.it/gstatico/documenti/dati_pedol/servizi_ecosistemici_suoli.pdf

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Thanks for your kind attention!

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