Carbon in Urban Soils

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Funding Stakeholders

- **Federal Office for the Environment (FOEN), Soil Section**
- **Canton de Vaud, Direction Générale du Territoire et du Logement (DGTL)**

● Introduction. Understanding organic carbon in soils and urban redevelopment

● Results. Urban soil organic carbon and its drivers

● Application. Strategic guidelines to improve soil carbon sequestration in urban redevelopment projects

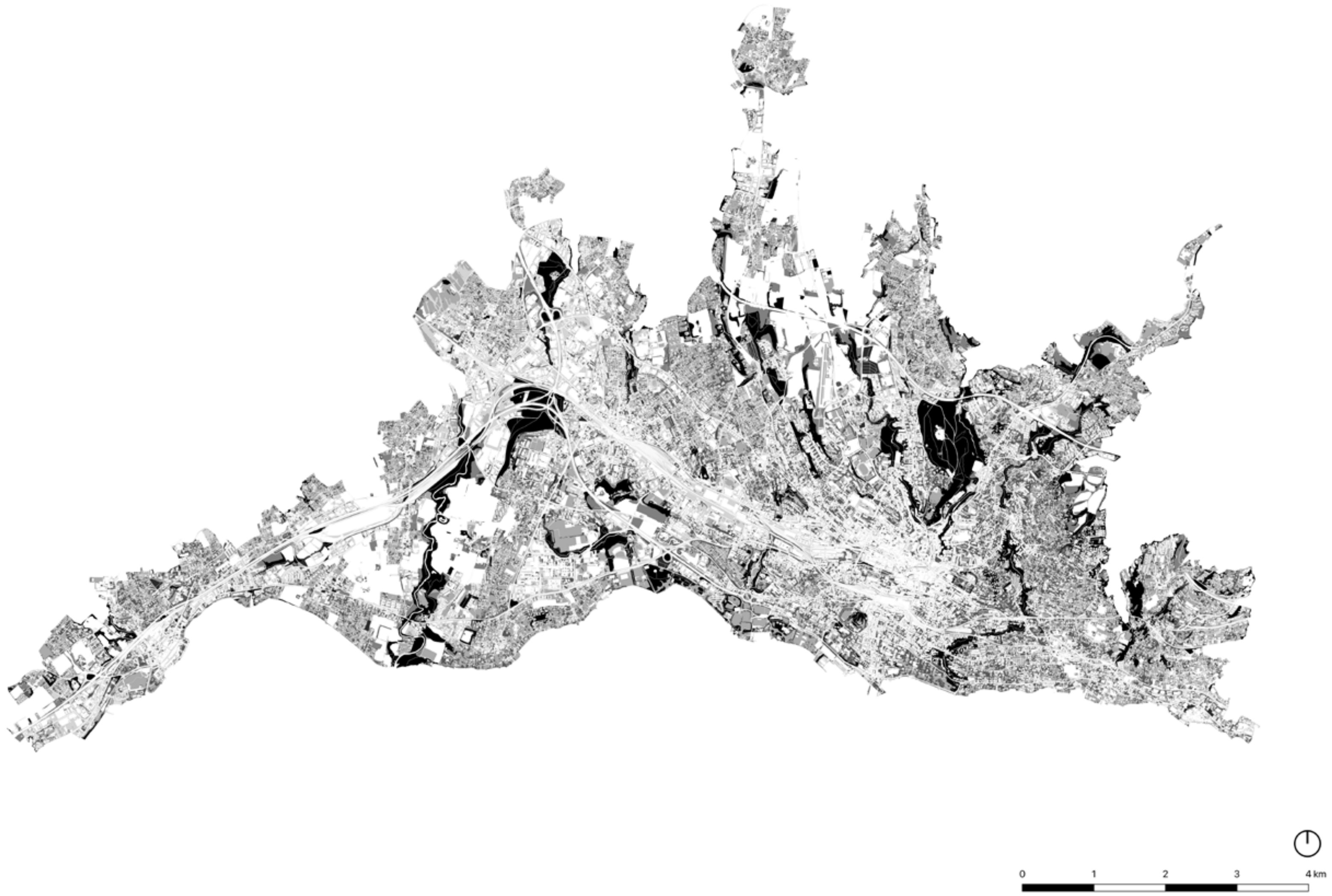
● Conclusion. Towards further research and implementation

a Through field survey and measurement (organic carbon, bulk density, texture, calculation of SOC and SOC stock, MO/Clay) assessing the current amount of carbon in Swiss urban soils (Lausanne and Zurich);

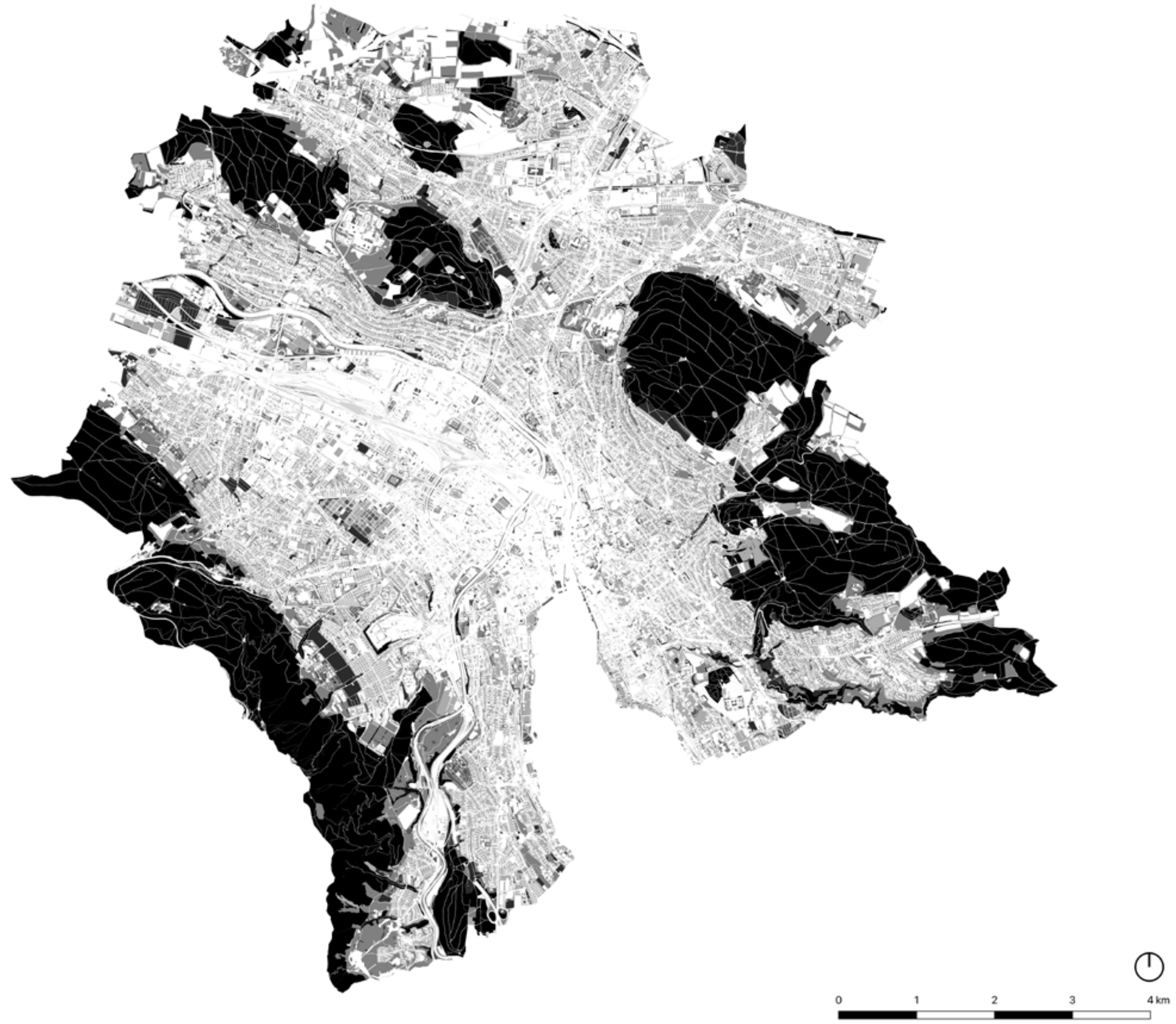
b Interpreting the SOC variation according to two main drivers: geomorphology (influencing soil texture, clay content) and vegetal cover and related management practices (influencing organic matter input);

c Understanding the effect of urban planning/design/management on soil carbon sequestration (agglomeration projects);

d Elaborating strategic guidelines to improve carbon sequestration in urban soils in the framework of urban redevelopment projects.



Simplified map of vegetation cover of Lausanne (Lausanne-Morges agglomeration)



Simplified map of vegetation cover of Zurich (city)

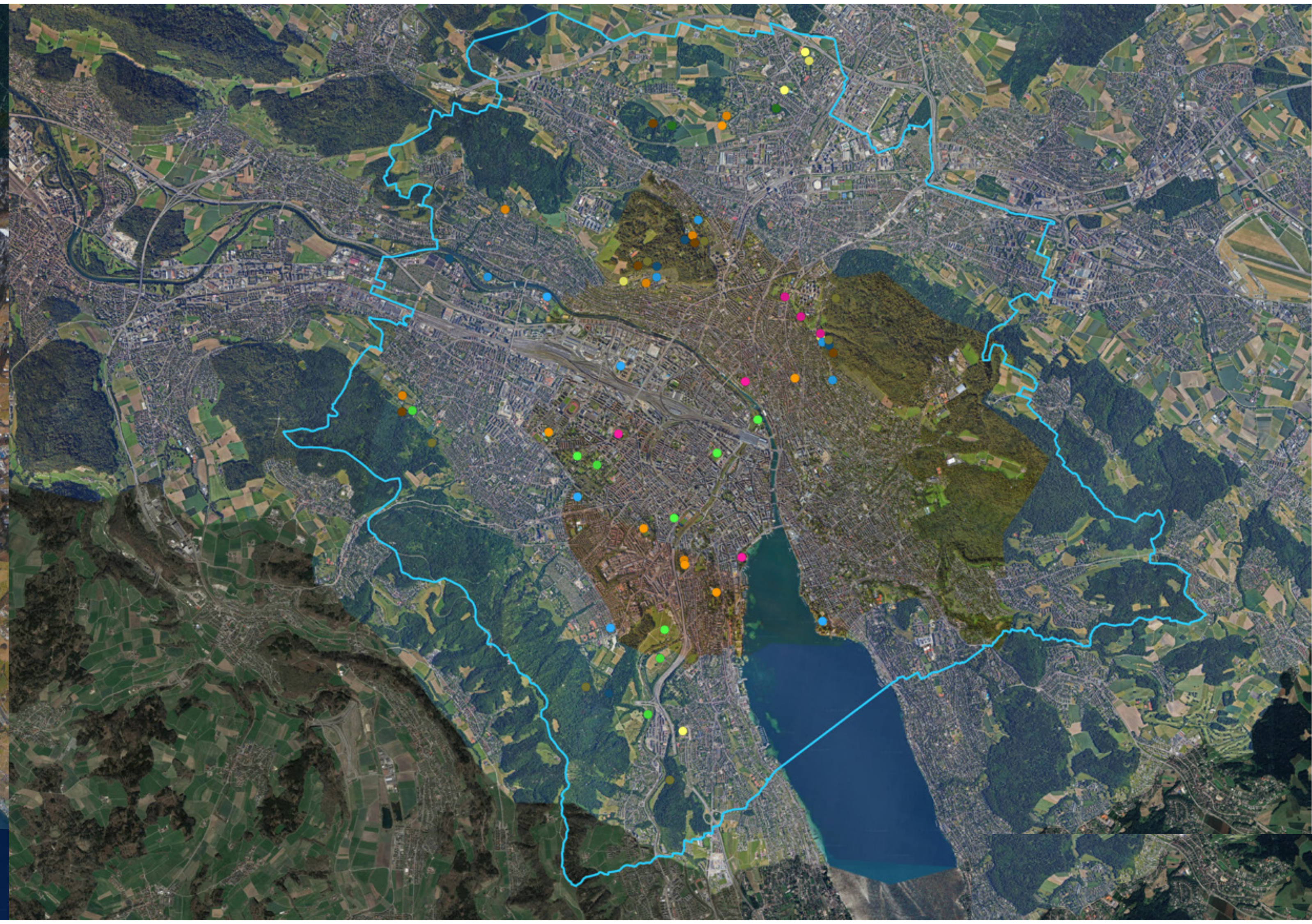
Pedological observations on the first 20 cm of soil, according to the studied vegetation covers types

- Forest
- Vegetable garden
- Urban plantation
- Meadow
- Lawn
- Ruderal
- Not taken into account in the classification (agricultural and artificialized surfaces)

Shades of gray representing the different vegetation cover types and related maintenance practices according to a hypothesized gradient of organic matter input

Main focus on 4 types of vegetation cover.

Map of soil sampling sites in the Lausanne-Morges agglomeration



Map of soil sampling sites in Zurich City

Vegetation cover types	Total Numbers of samples	Lausanne	Zurich	This project	Tresch et al., 2018	Singer, 2023
Forest	30	11	19	30	0	0
Garden (vegetable)	10	10	0	10	0	0
(Private) P-garden (vegetable)	83	0	83	0	83	0
Meadow	33	12	21	31	0	2
Lawn	34	12	22	26	0	8
(Private) P-lawn	58	0	58	0	58	0
Total	**248**	**45**	**203**	**97**	**141**	**10**

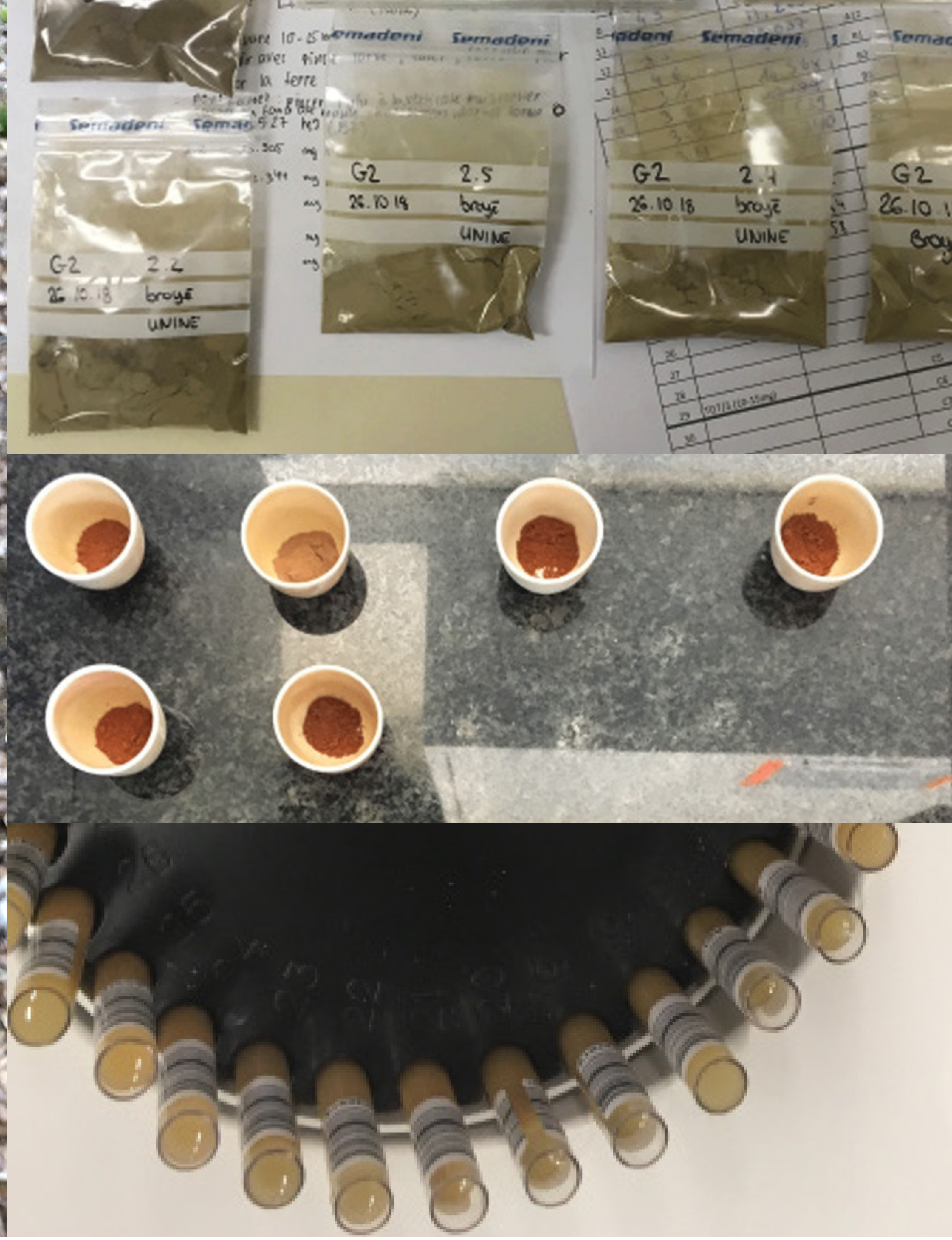
Summary of samples by vegetation types, cities, and sources

- Sandstone- Marl
- Bottom moraines
- Ablation moraines and coarse alluvium
- Lacustrine and fine alluvial deposits
- Anthropogenic landfill

Color swatch representing the different geo-morphologies as secondary sampling selection criteria

248 sites considered in total.

Composite sample (5 sub-samples; 20 cm)



Total Carbon: CHN elemental analyzer; Inorganic Carbon: HCl fumigation for carbonate determination; Organic Carbon: Ctot – Cinorg; Texture: Laser granulometry; Bulk Density: Sampling of an undisturbed soil core of known volume and weighing of the oven-dried fine earth fraction

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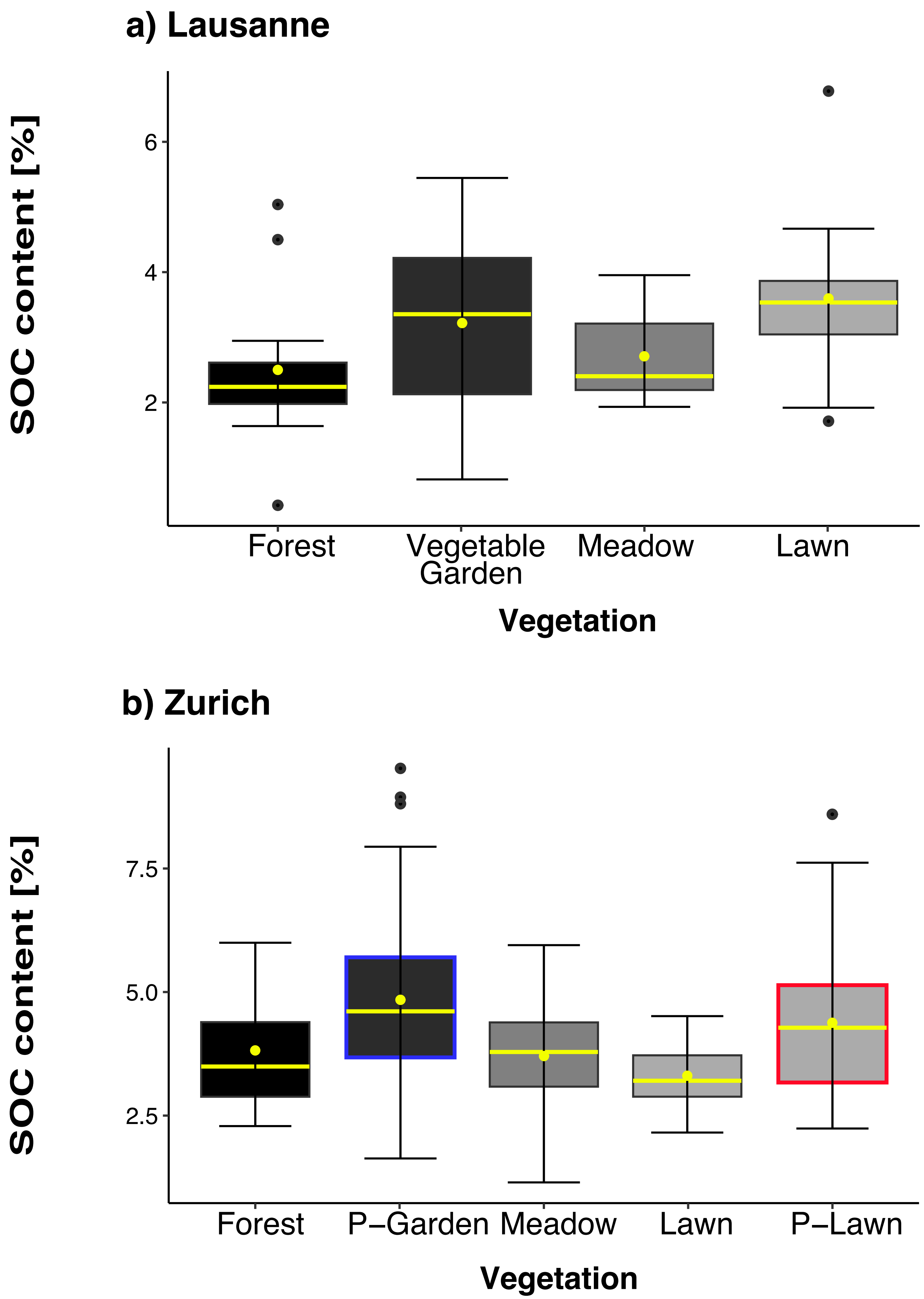
Topsoil SOC values of Zurich and Lausanne's green spaces are relatively typical when compared to other global cities, slightly lower compared to Swiss grasslands, and considerably higher than Swiss croplands.

Location	Vegetation	Mean SOC content %	SOC% Variation	SOC stocks (t/ha)	Stock Variation	Citation
Lausanne	Forest	2.5	0.65	46.4	23.5	-
Lausanne	Vegatable Garden	3.3	1.43	61.6	29.3	-
Lausanne	Meadows	2.7	1.02	62.4	16.9	-
Lausanne	Lawn	3.59	1.31	74.9	22.2	-
Zurich	Forests	3.82	1.42	80.49	44.3	-
Zurich	(Private) P-garden	4.85	2.47	NA	-	Tresch et al. 2018
Zurich	Meadow	3.7	1.45	76.6	27.6	-
Zurich	Lawn	3.31	0.38	70.3	14.9	-
Zurich	(Private) P-lawn	4.38	1.98	NA	-	Tresch et al. 2018
Atlanta	Forest	-	-	77	-	Pouyat et al. 2006
Atlanta	Park	-	-	71	-	Pouyat et al. 2006
Berlin	Forest	-	-	72.7	-	Richter et al. 2020
Berlin	Forest	-	-	58	-	Klingenfuß et al. 2019
Berlin	Meadow	-	-	74.8	-	Richter et al. 2020
Berlin	Park	-	-	70.2	-	Richter et al. 2020
Berlin	Park	-	-	75	-	Klingenfuß et al. 2019
Switzerland	Grassland	-	-	81.7	-	Moll-Mielewczik et al. 2023
Switzerland	Cropland	-	-	40.6	8.9	Leifeld et al. 2005
Berlin	Cropland	-	-	44	9	Klingenfuß et al. 2019
Canton Vaud	Cropland	1.45	-	-	-	Dupla et al. 2021
Canton Jura	Cropland	2.3	-	-	-	Johannes et al. 2023
Canton Zurich	Cropland	2.7	-	-	-	Kanton Zurich, 2022

Summary table of SOC % and SOC stock (t/ha) as well as the variation (given as the interquartile range) for each of the vegetation types and cities. Results found in the literature were included as a point of comparison.

While Lausanne displays a high degree of variability, making it difficult to identify any main trends related to vegetation cover types, in Zurich, lawns tended to have reduced SOC stocks compared to meadows, whereas urban forest soils contain the highest SOC.

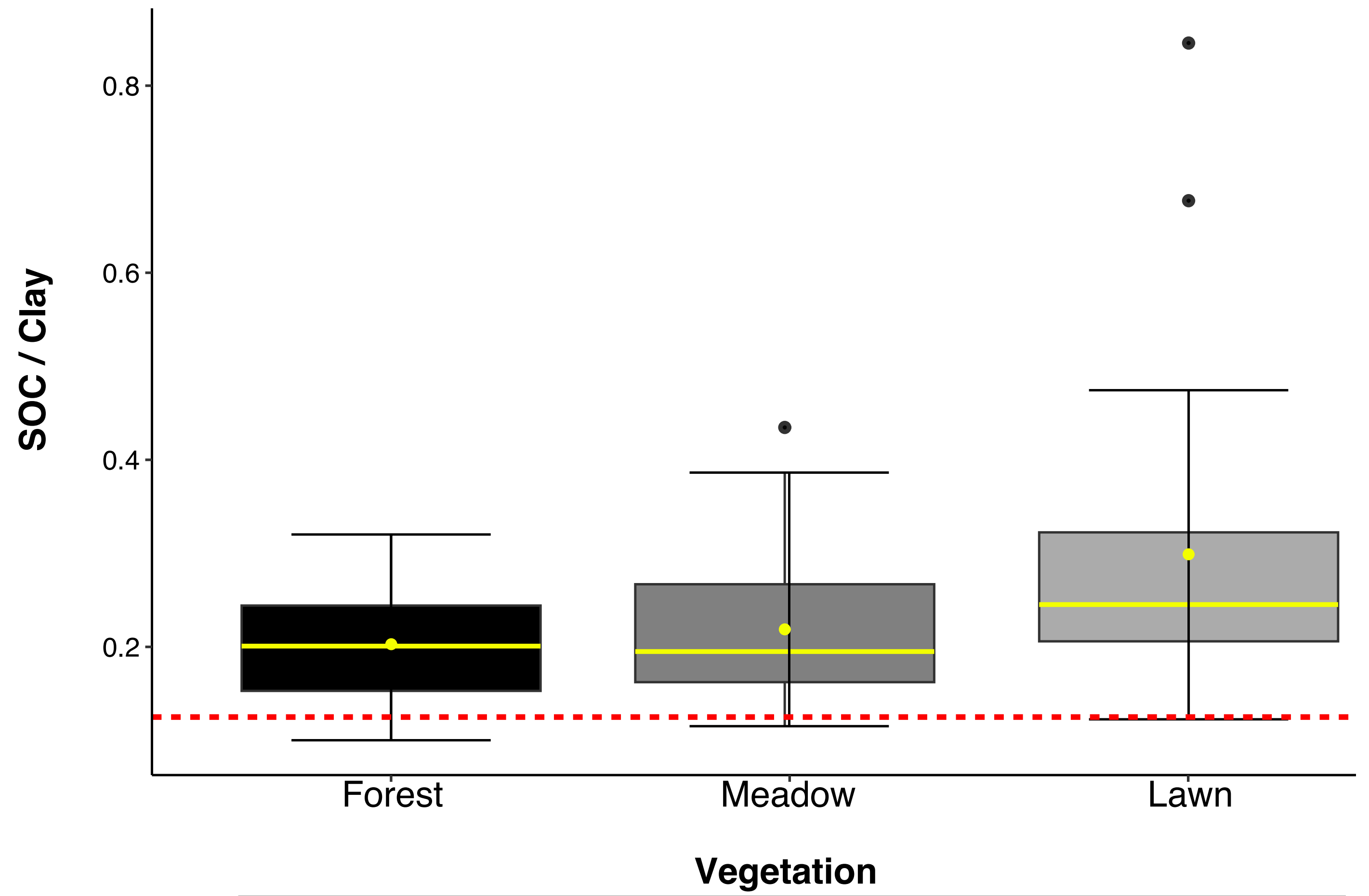
Privately owned gardens exhibit significantly higher SOC levels than public green spaces in either city, likely due to differing management practices.



Boxplots showing the distribution of the SOC percentage [%]

The present project supports the notion of sequestration potential to be used as a target, expressed as a SOC/Clay ratio defined in accordance with specific soil function(s) sought as co-benefits. In the urban context, the co-benefit sought is not just food production, but a more holistic notion of territorial adaptation to climate change (resistance and resilience), including in particular the water regulation functions.

In urban environments, the possible levers for increasing organic carbon in soils are not limited to protecting existing stocks and improving cultivation and management practices, but also include the reconstitution of functional in currently artificialized and sealed areas.



Boxplots showing the distribution of SOC/Clay ratio in Zurich (public green spaces). The threshold ratio of 1/8 (0.125) indicating a very well-structured soil is denoted as the dashed red line.

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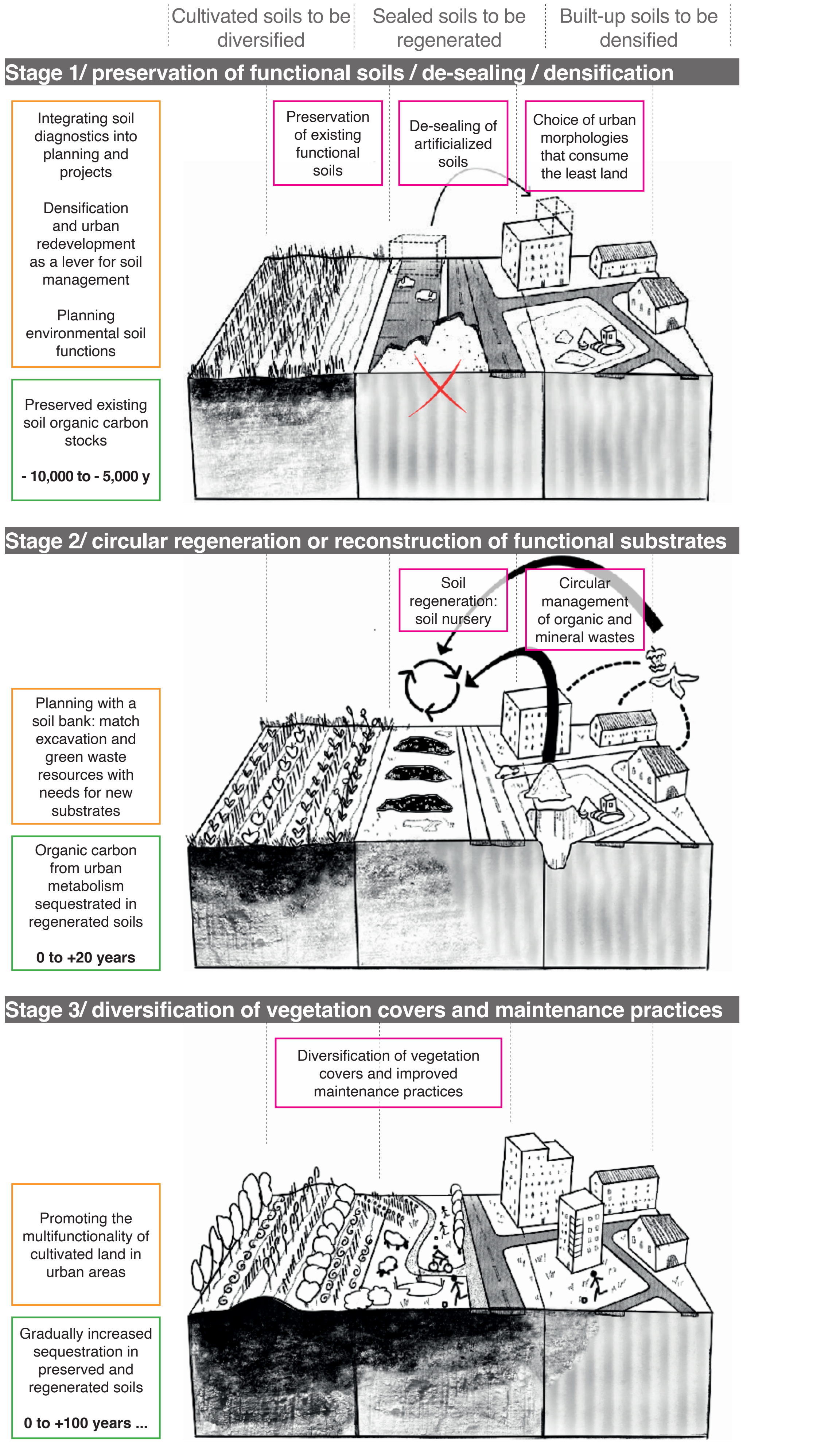
An overall process in 3 steps:

● Preserving existing functional soils;
● Regenerating soils on currently artificialized surfaces;
● Improving and diversifying the vegetation cover and related management.



The three stages of the overall process aiming to increase the organic carbon sequestration capacity of urban soils. Evolving triptych diagram, showing schematically for each stage: levers for action in terms of densification and urban redevelopment projects (in pink); methodological challenges for the urban planners (in orange); impact on carbon sequestration at different timescales (in green).

Cultivated soils to be diversified | Sealed soils to be regenerated | Built-up soils to be densified

Stage 1/ preservation of functional soils / de-sealing / densification

Integrating soil diagnostics into planning and projects

Densification and urban redevelopment as a lever for soil management

Planning environmental soil functions

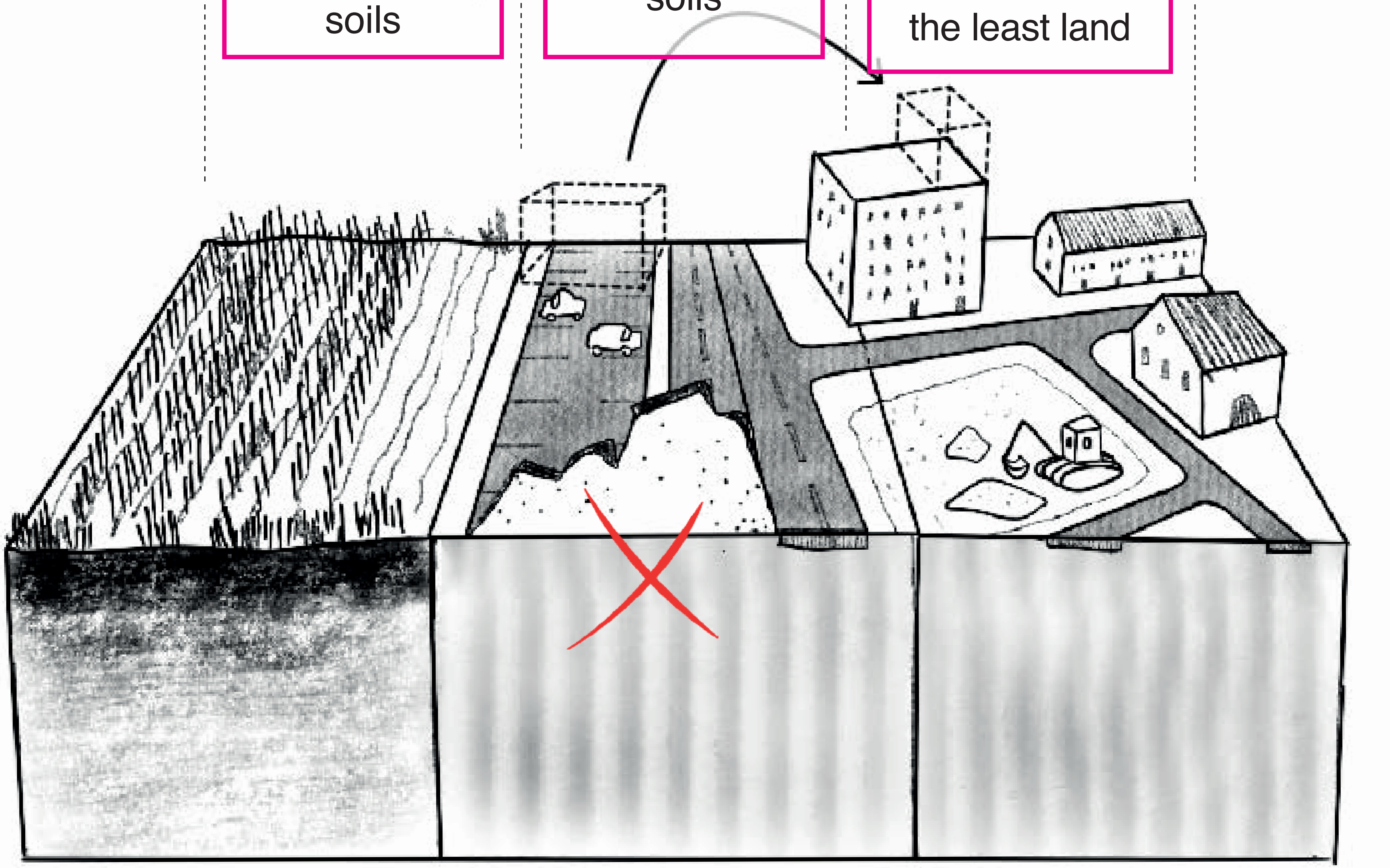
Preserved existing soil organic carbon stocks

- 10,000 to - 5,000 y

Preservation of existing functional soils

De-sealing of artificialized soils

Choice of urban morphologies that consume the least land



“ URBAN MORPHOLOGY“ SCENARIO / THE VOID TYPES

Just like soils, the urban life needs space to breathe. Soil that is too compacted loses viability and so does the city. To be sustainable, the densification of cities should therefore not consist in feeling the remaining voids in the urban fabric, but rather “intensifying” the social and ecological performances of all built and unbuilt surfaces. Such intensification in urban, as well as environmental, uses and functions entail identifying the different types of voids and their interconnections. This classification defines the “granularity of urban forms” (the size of voids in relation to built footprints) and allow for choosing building morphologies that consume as little land as possible.

- **Building Footprints**
- **Agricultural Patches**
  e.g. cropland, pastures
- **Preserved Ecosystems**
  e.g. creeks, forests, meadows
- **Infrastructural Bundle**
  e.g. railyways, highways
- **Urban Public Centralities**
  e.g. schoolyards, sport fields, esplanades, other commons
- **Urban Private Grid**
  e.g. private gardens
- **Industrial Platforms**
  e.g. large parking lots and logistic area

0 2km

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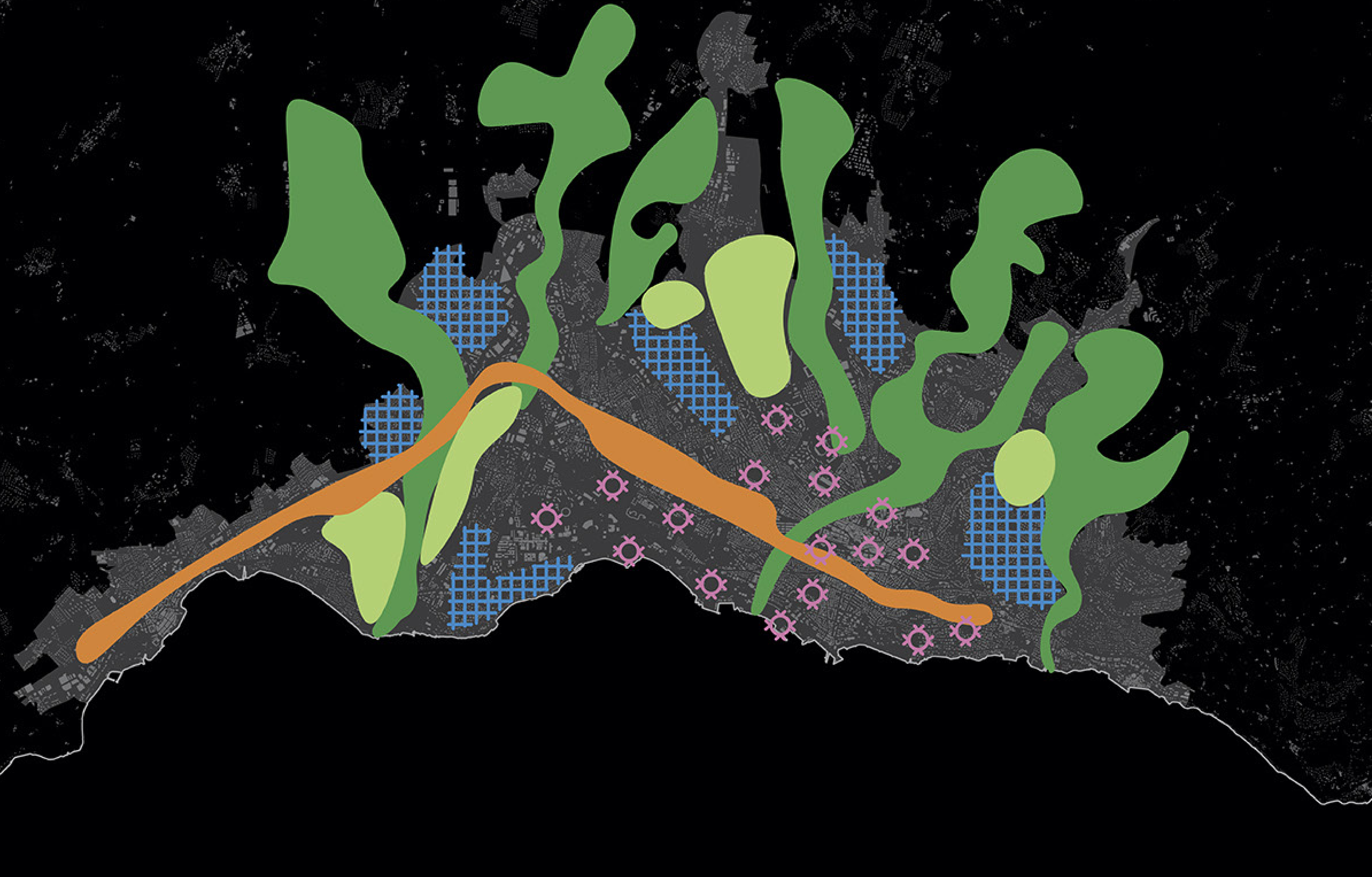
“ URBAN MORPHOLOGY“ SCENARIO / NETWORK OF VOIDS

Intensifying urban voids entail preserving the voids in which soils are still functional, and regenerating or restoring the ecological value of the voids in which soils are artificialized. The combined action of preservation and regeneration therefore defines a “network of voids” that structure the urban fabric at different scales: connecting the North/South wooded strips running along rivers to the larger West/Est infrastructural bundle of the former glacial valley, passing through the grid of private gardens forming a continuum, punctuated by the centralities of public voids clusters formed by schoolyards, sport fields, public squares and other commons. Such network facilitates the circulation of air, water, and biodiversity fluxes throughout the city and provide a wide range of climate-resilient leisure areas for the inhabitant.



Building Footprints

Agricultural Patches
e.g. cropland, pastures

Preserved Ecosystems
e.g. creeks, forests, meadows

Infrastructural Bundle
e.g. railyways, highways

Urban Public Centralities
e.g. schoolyards, sport fields, esplanades, other commons

Urban Private Grid
e.g. private gardens

0 2km

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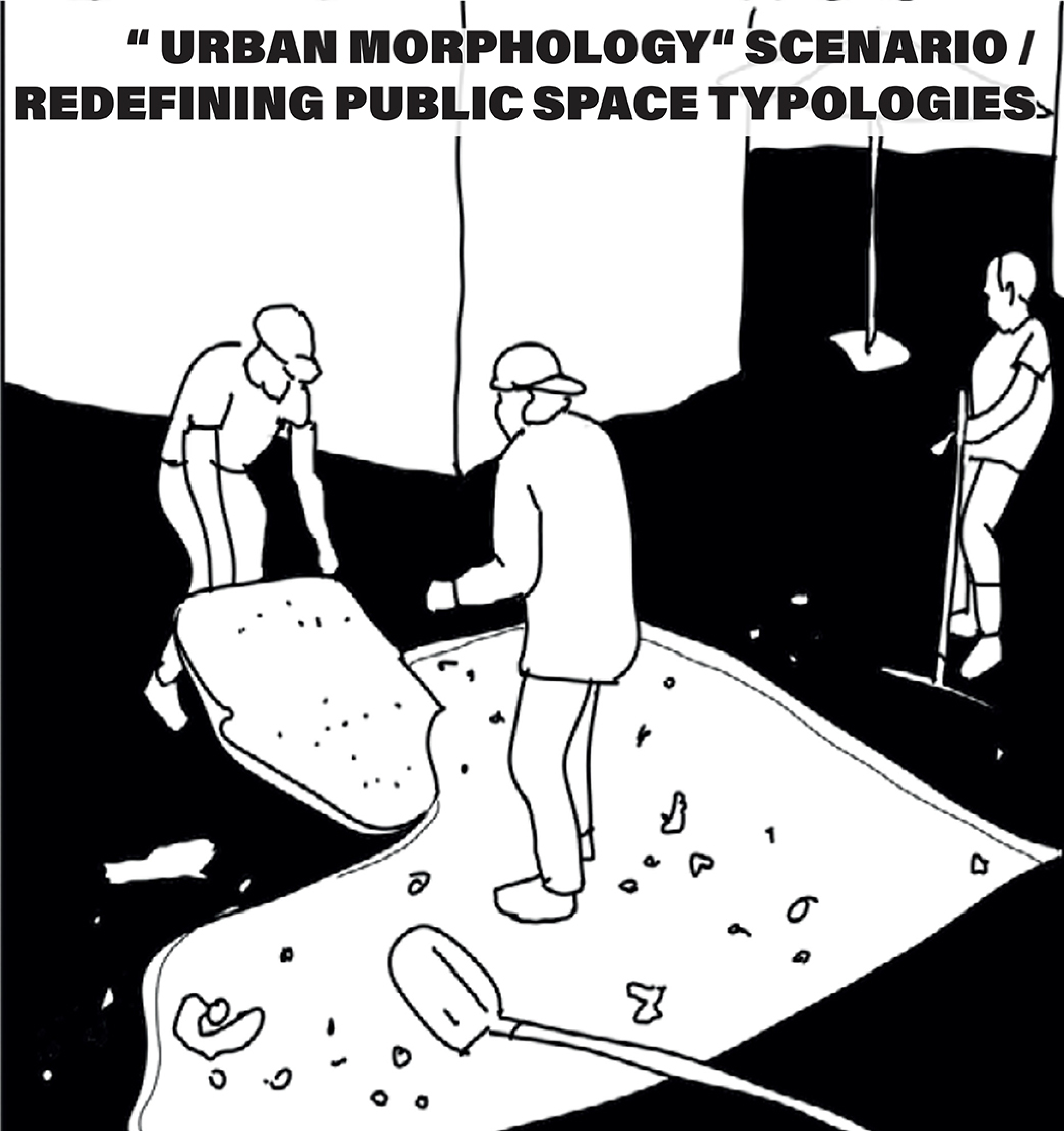
" URBAN MORPHOLOGY" SCENARIO / REDEFINING PUBLIC SPACE TYPOLOGIES

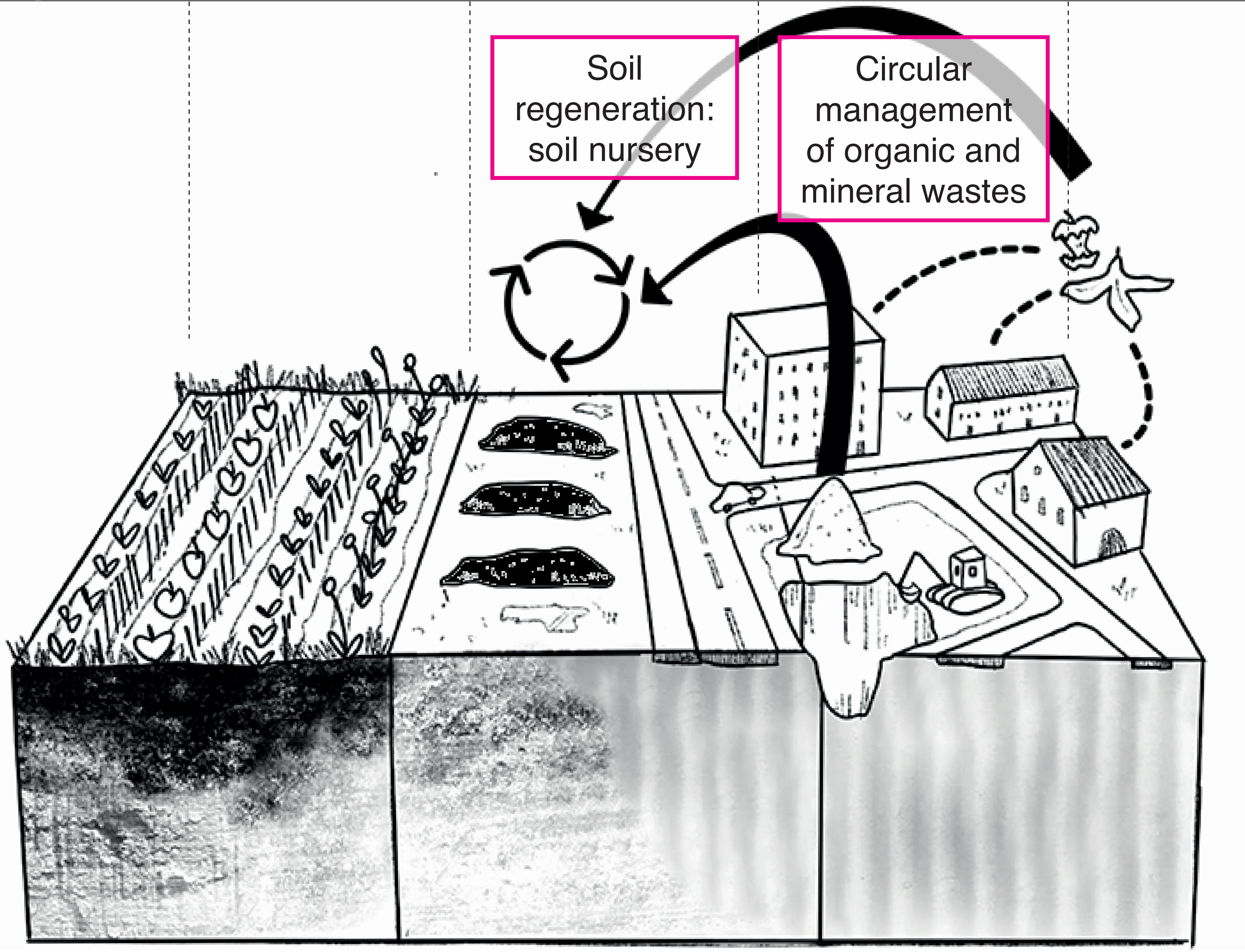


Stage 2/ circular regeneration or reconstruction of functional substrates

Planning with a soil bank: match excavation and green waste resources with needs for new substrates

Organic carbon from urban metabolism sequestrated in regenerated soils

0 to +20 years



“ URBAN METABOLISM“ SCENARIO / TOWARDS THE CIRCULARITY OF GREEN AND MINERAL RESOURCES

Urban green and construction wastes can be used to create purpose-designed and functional soils. Instead biological and sedimental resources are mostly exported outside the urban environment, which, in turn, consume ‘healthy’ soils to create green spaces. We need to enhance circularity by processing urban green and mineral waste into new soils.

Fluxes
Organic and sedimental resources are often considered waste. At best, organic material is used for biogas production and sedimental material for road construction. However, a large proportion ends up in landfills, damaging the surroundings. These fluxes need to be redirected.

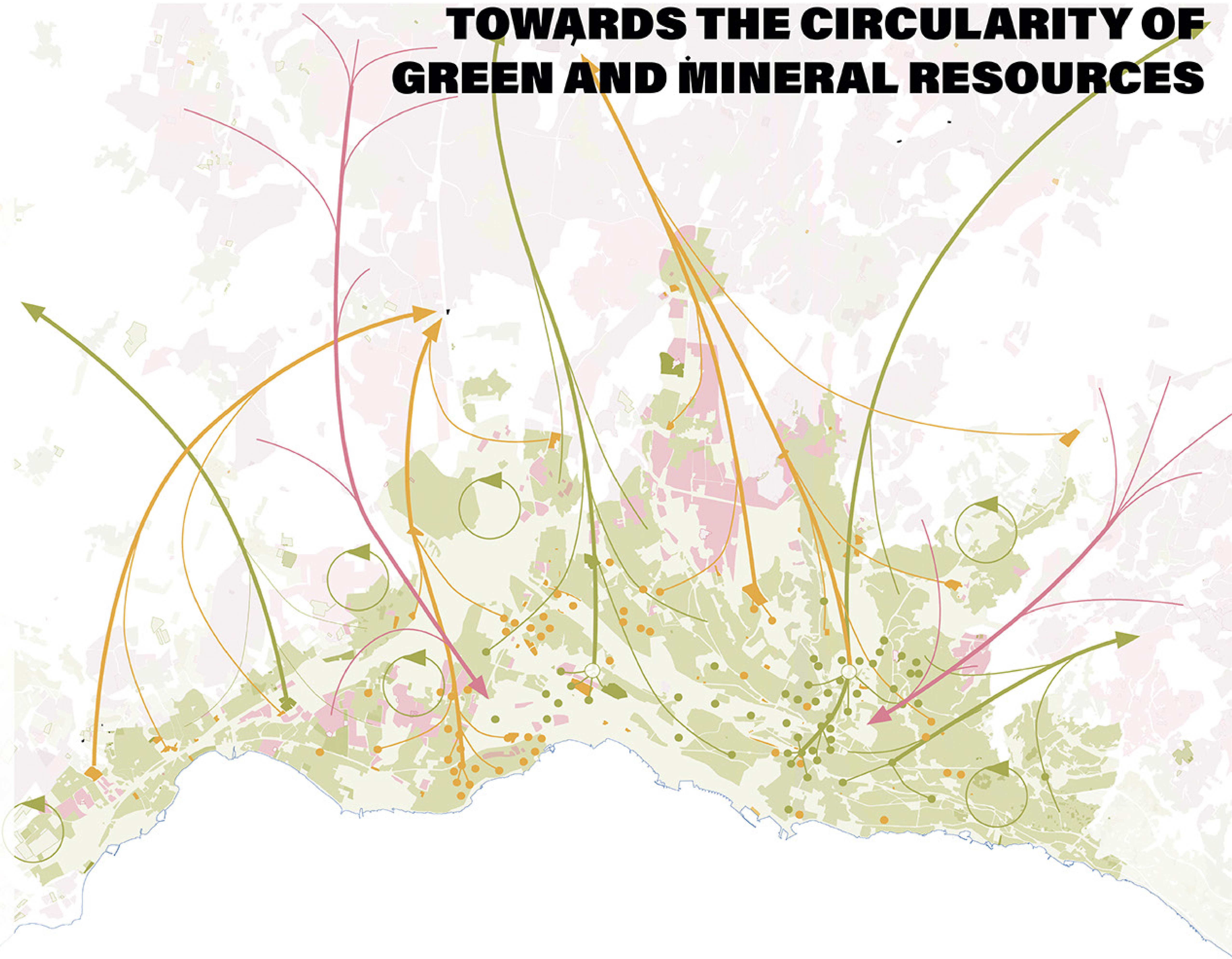
When ‚healthy‘ soil is needed in the city, it is usually dug up from agricultural land. The surrounding countryside is thus exploited in two ways. These fluxes need to become obsolete.

Few processes already work in a circular way. For example, private organic waste, used as compost in suburban gardens to grow crops. Circularities like these need to be enhanced.

Organic Ressources

Sedimental Ressources

Landfills



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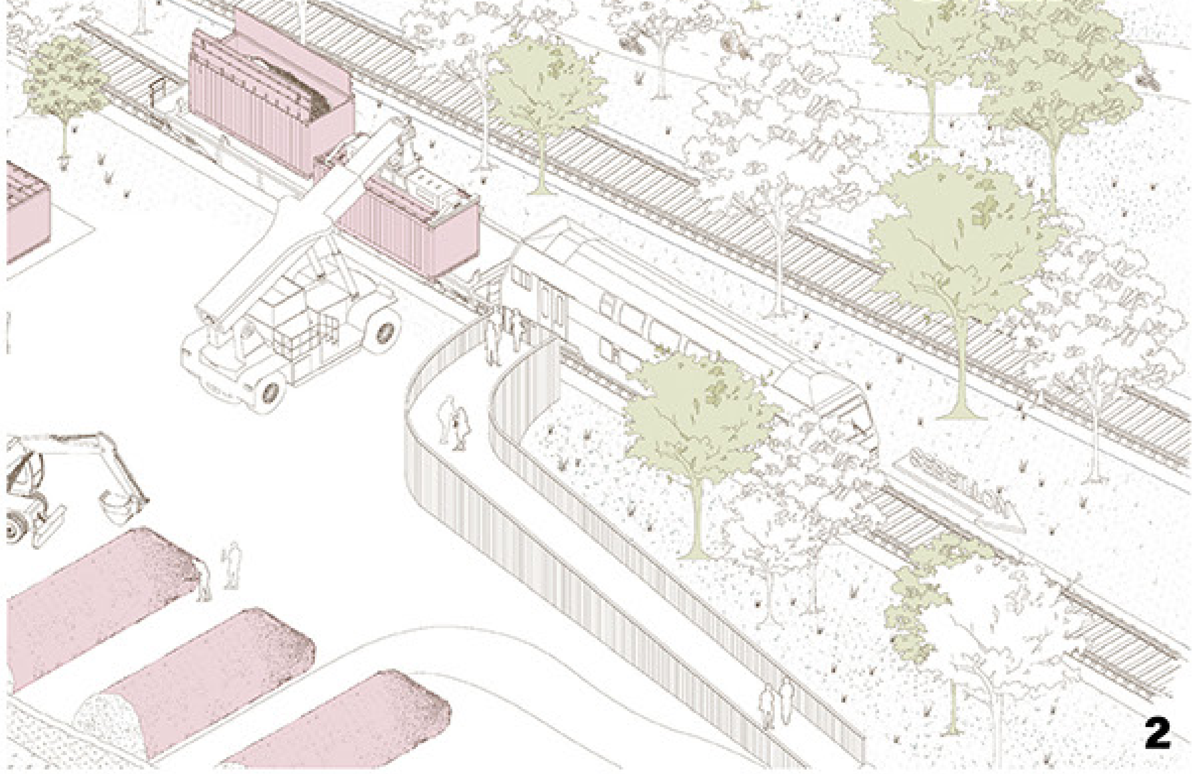
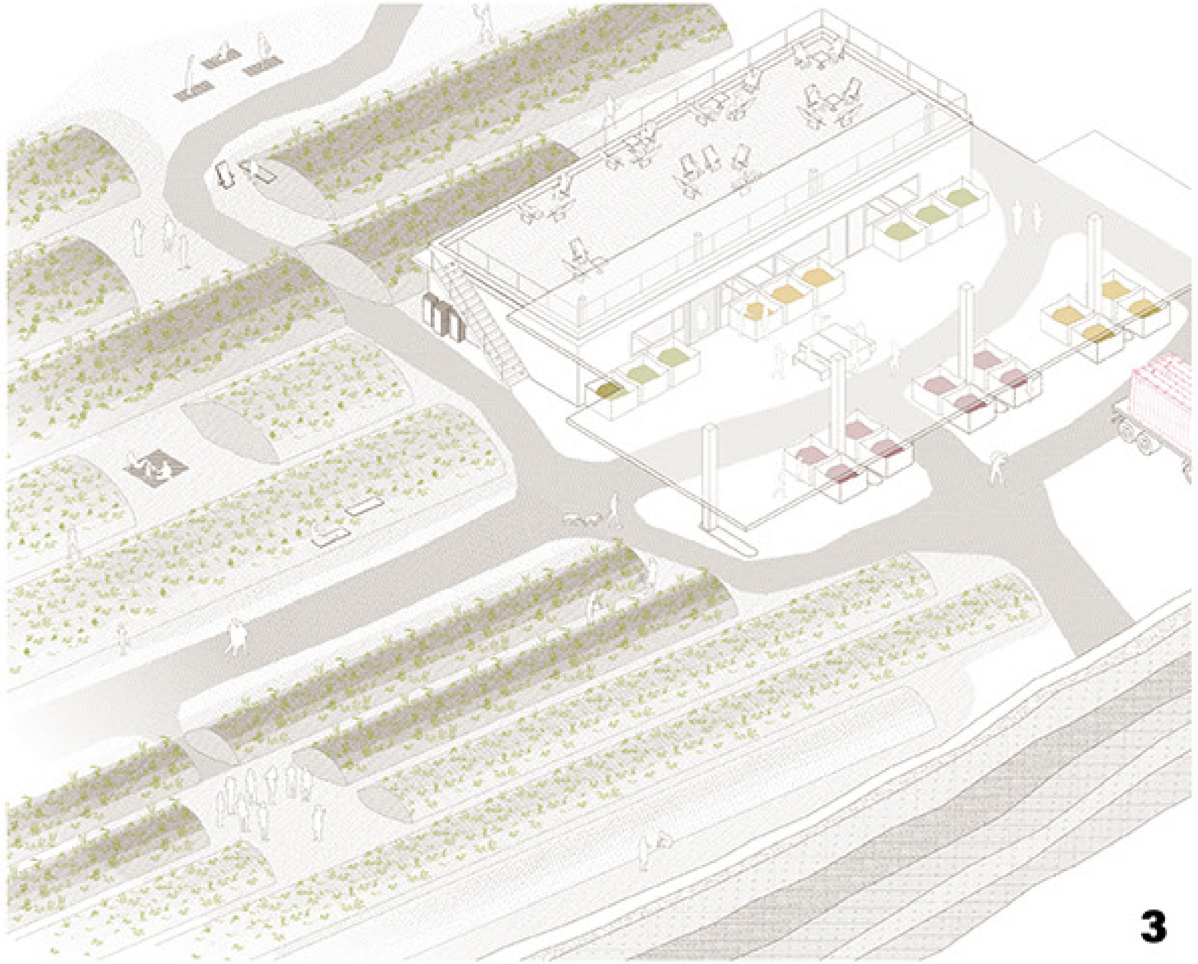
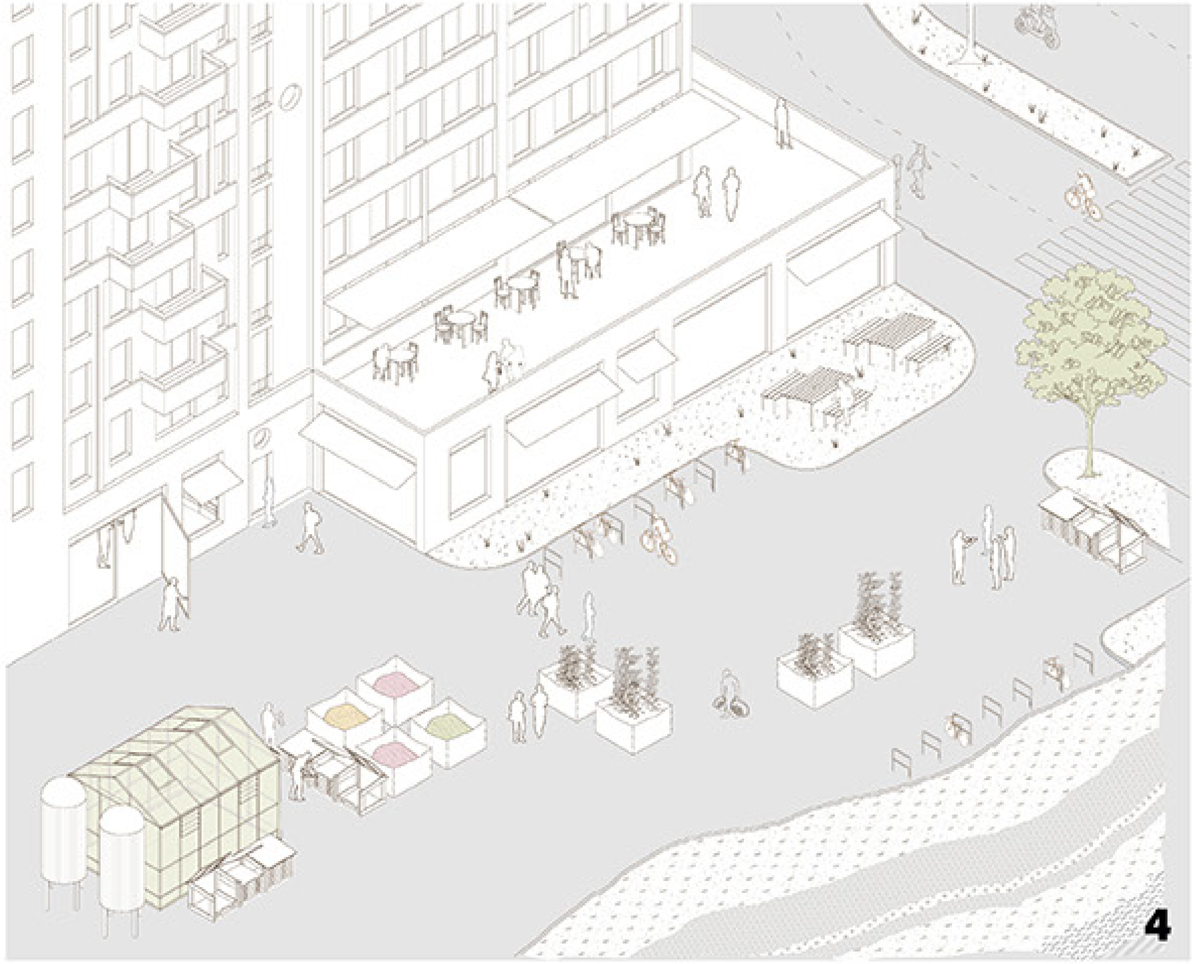
" URBAN METABOLISM" SCENARIO / SOIL FARMS, NURSERIES AND LABORATORIES AS NEW URBAN LANDSCAPES

The Soil Factory in Lonay SSD processes waste into soil substrate by composting organic resources and crushing, washing, and sorting sediments. This base material can become living soil when mixed correctly. Located on a former industrial site in Lonay, the factory uses nearby railway infrastructure to send non-matured soil to Sebeillon. In the Soil Nursery, this base material matures into living soil in the city center, enhancing urban awareness of soil and material cycles. The soil from Lonay is piled, planted, and left to mature for a year, transforming into functional soil through plant growth and microbial activity. The nursery offers public engagement through guided tours, information boards, workshops, and a terrace. The Soil Laboratory evaluates and creates knowledge about soil production. Soil scientists conduct research on urban soil development and functions. Connected with the educational center, the laboratory aims to expand soil farming across the region and beyond, requiring immediate funding through research contracts. This laboratory, part of the Sebeillon complex, will be a leading center of soil science







1 Soil Factory collecting point

2 Soil Factory send off point

3 Soil Nursery Sébeillon West

4 Soil Laboratory Sébeillon Est

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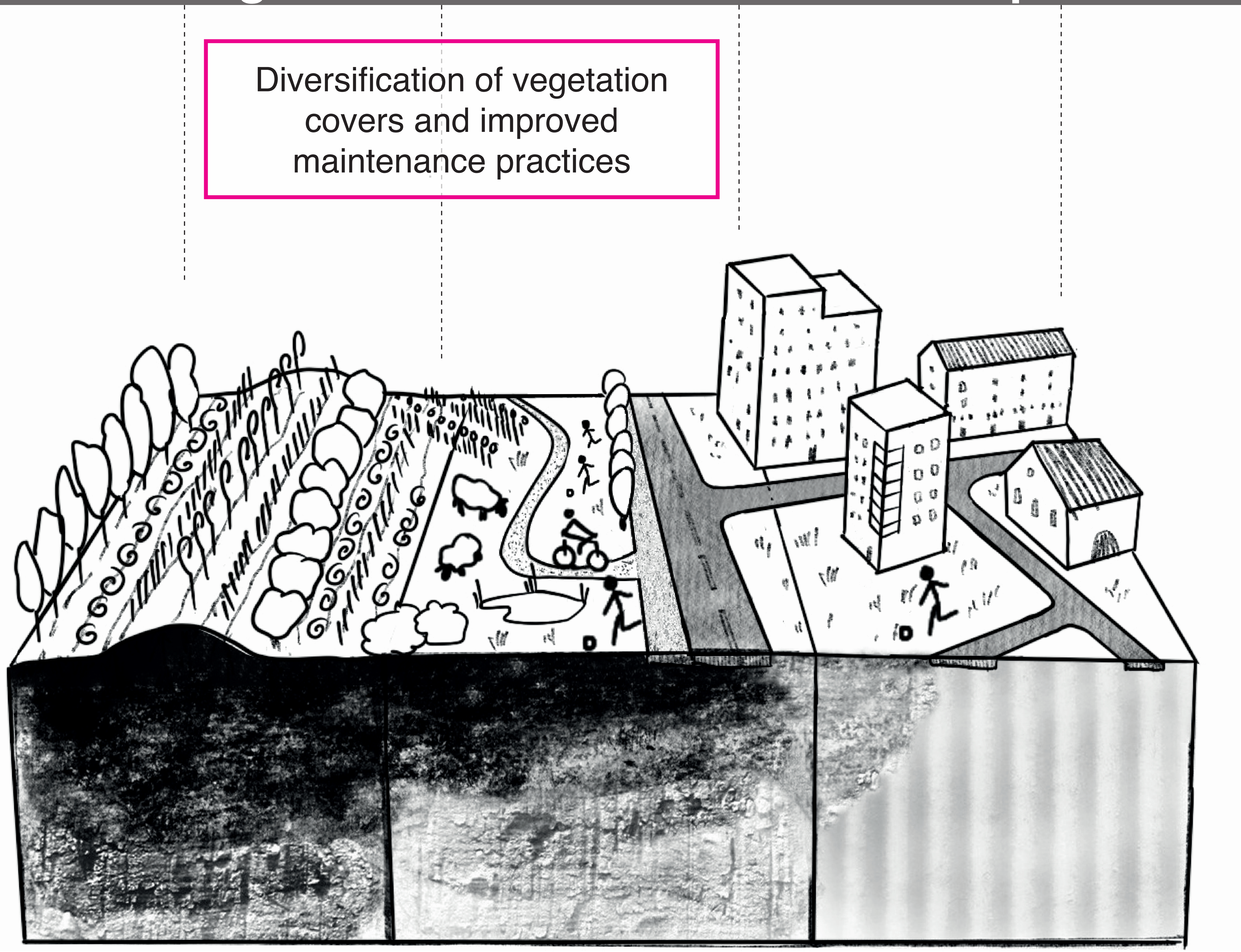
Stage 3/ diversification of vegetation covers and maintenance practices

Diversification of vegetation covers and improved maintenance practices

Promoting the multifunctionality of cultivated land in urban areas

Gradually increased sequestration in preserved and regenerated soils

0 to +100 years ...

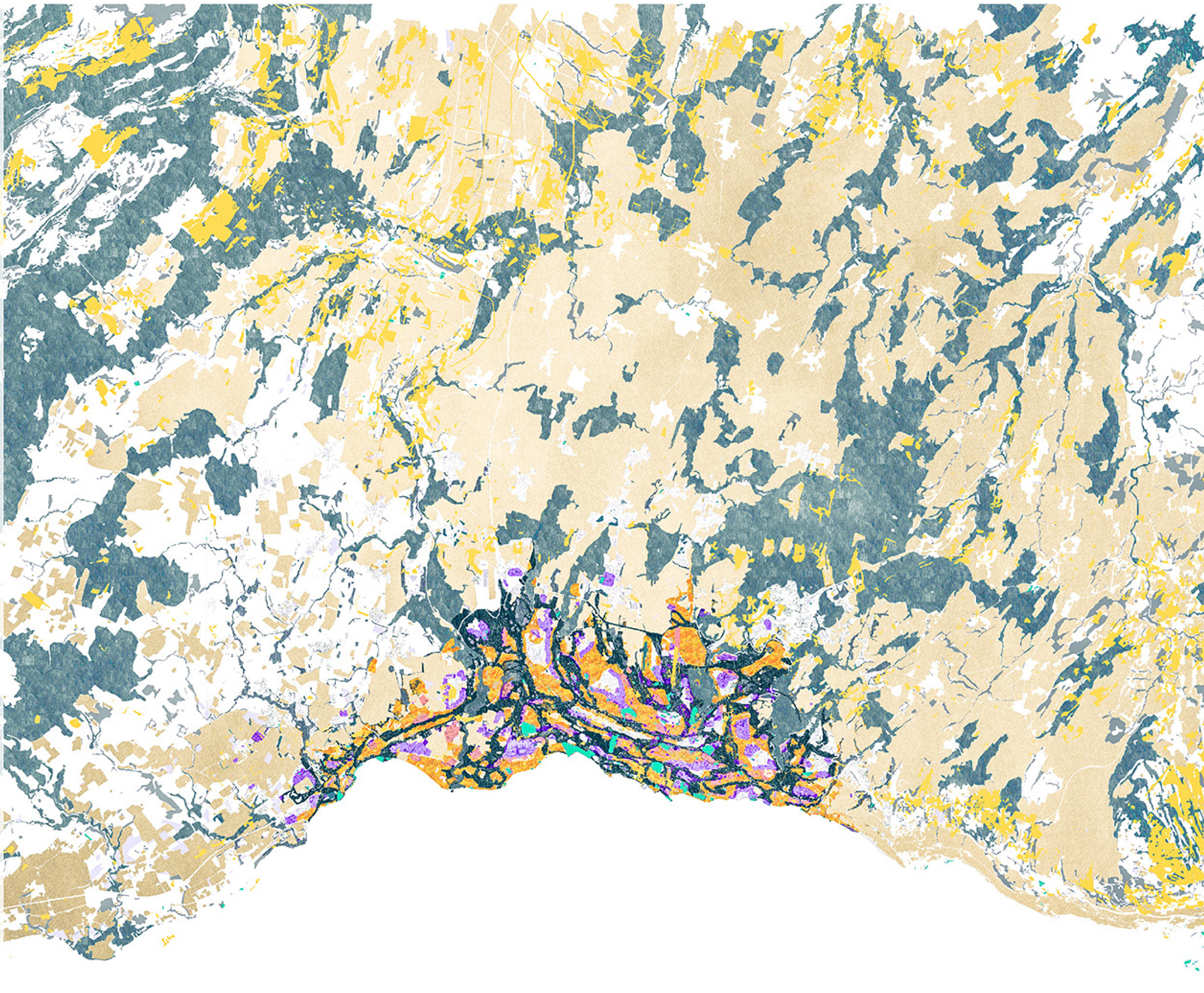


" URBAN NATURE" SCENARIO / THE GREEN NETWORK

Vegetation cover and land management practices have an impact on soil health and carbon sequestration capacity. Strategies to increase soil organic matter input include transforming existing meadows, parks and lawns into perennial pastures which introduce long-lived and deep-rooted plants into the urban fabric, that maintain consistent soil cover and enhance soil structure and carbon retention. Agricultural practices such as crop rotation, cover cropping, polycultures, agroforestry and organic farming using integrated pest management as well as conservation tillage and composting ensure sustainable nutrient cycling and benefit soil fertility. Interconnecting private urban gardens into a network increases biodiversity and promotes a variety of plant species with diverse root systems. Together, these practices create a "Green Network" as sustainable urban landscape that regenerates damaged soils, enhances urban resilience and serves as a potent carbon sink.

- Existing Forest
- New Forest
- Existing Agriculture
- Existing Meadow
- Existing Parks, Lawns
- New Perennial Pasture
- Garden Ecosystems

0 1 2 4km



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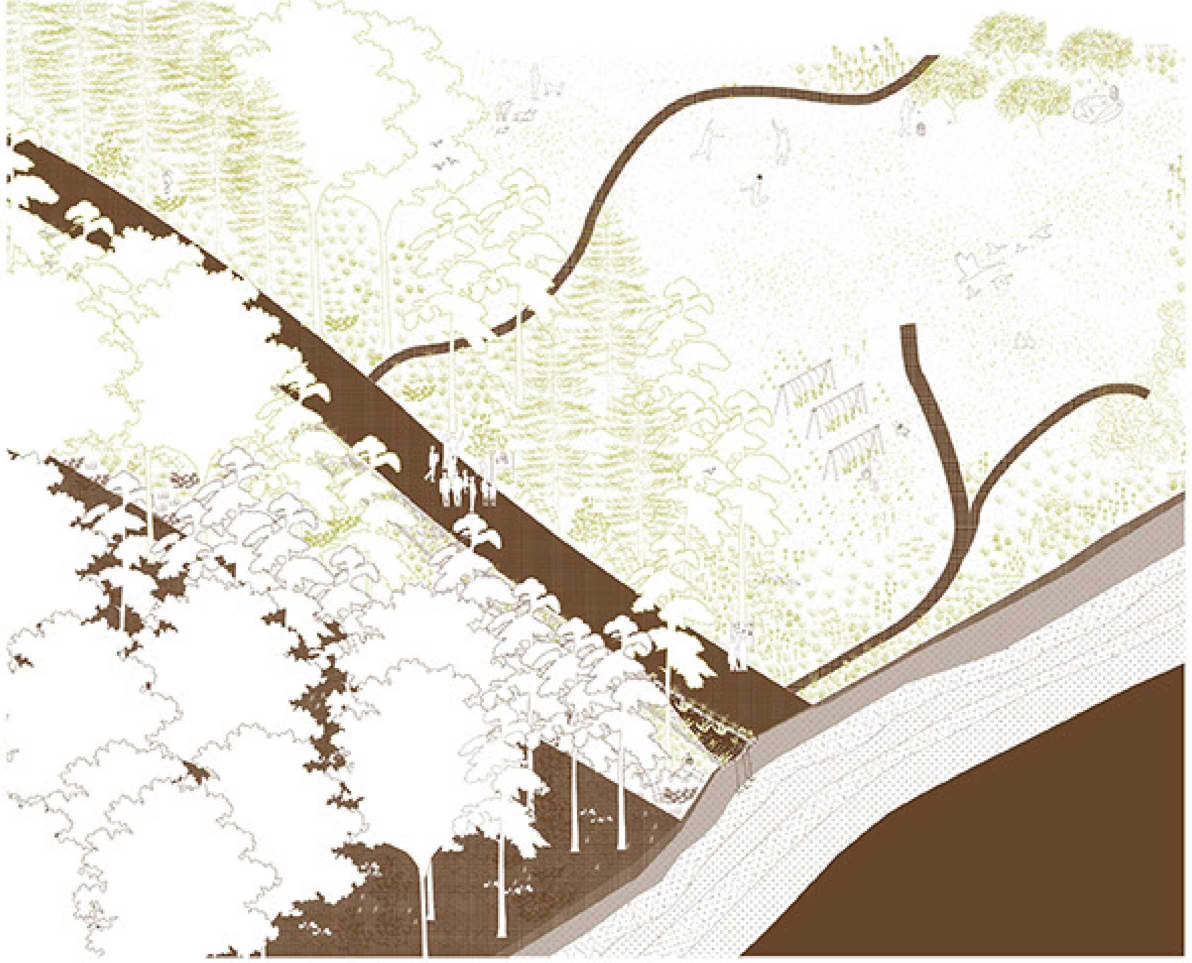
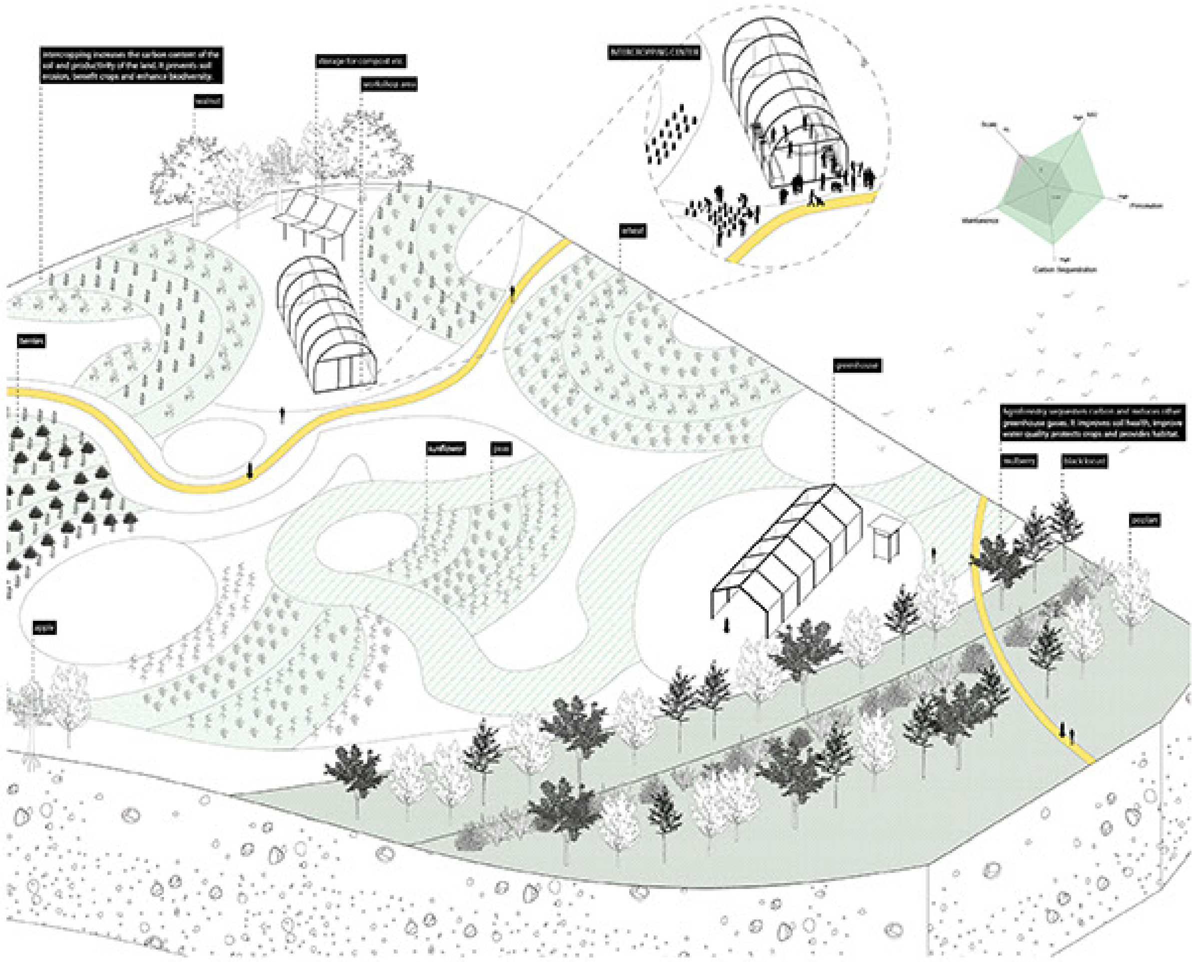
“ URBAN NATURE“ SCENARIO / 4 ECOLOGICAL HABITATS

Ecotones, or transitional areas between ecosystems, support rich biodiversity and deep-rooted plants, which increase soil organic matter and carbon storage. Preservation of existing vegetation ensures continuous organic matter input and protects soil from erosion, maintaining and enhancing soil carbon levels. Agroparks integrate agriculture with natural landscapes, fostering diverse plant species and sustainable practices like crop rotation and reduced tillage, boosting soil carbon. Silvopastures combine trees with livestock grazing, enhancing biomass and root depth while animals distribute organic matter, improving soil structure and carbon retention. Intercropping, or growing multiple crops together, increases plant diversity and organic residues, enriching the soil and promoting microbial activity, further enhancing carbon sequestration.

Collectively, these land management practices create a resilient and productive soil ecosystem. By integrating biodiversity and sustainable agricultural techniques, they significantly boost soil carbon sequestration, helping mitigate climate change while improving soil health and productivity.





1Ecotone Lonay SSD
2Preservation Lonay Villa-Est
3Agropark & Silvopasture
4Intercropping Center

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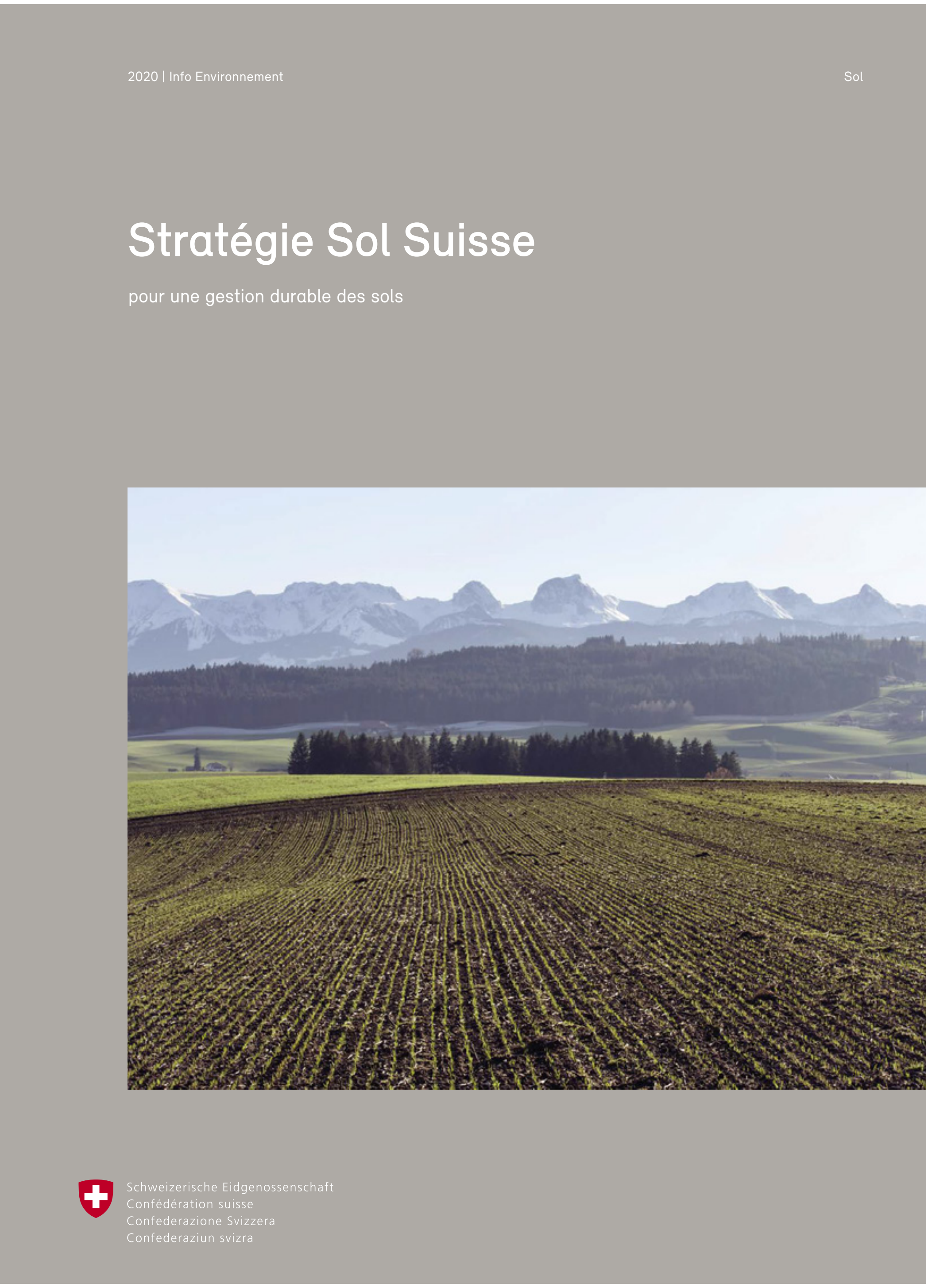
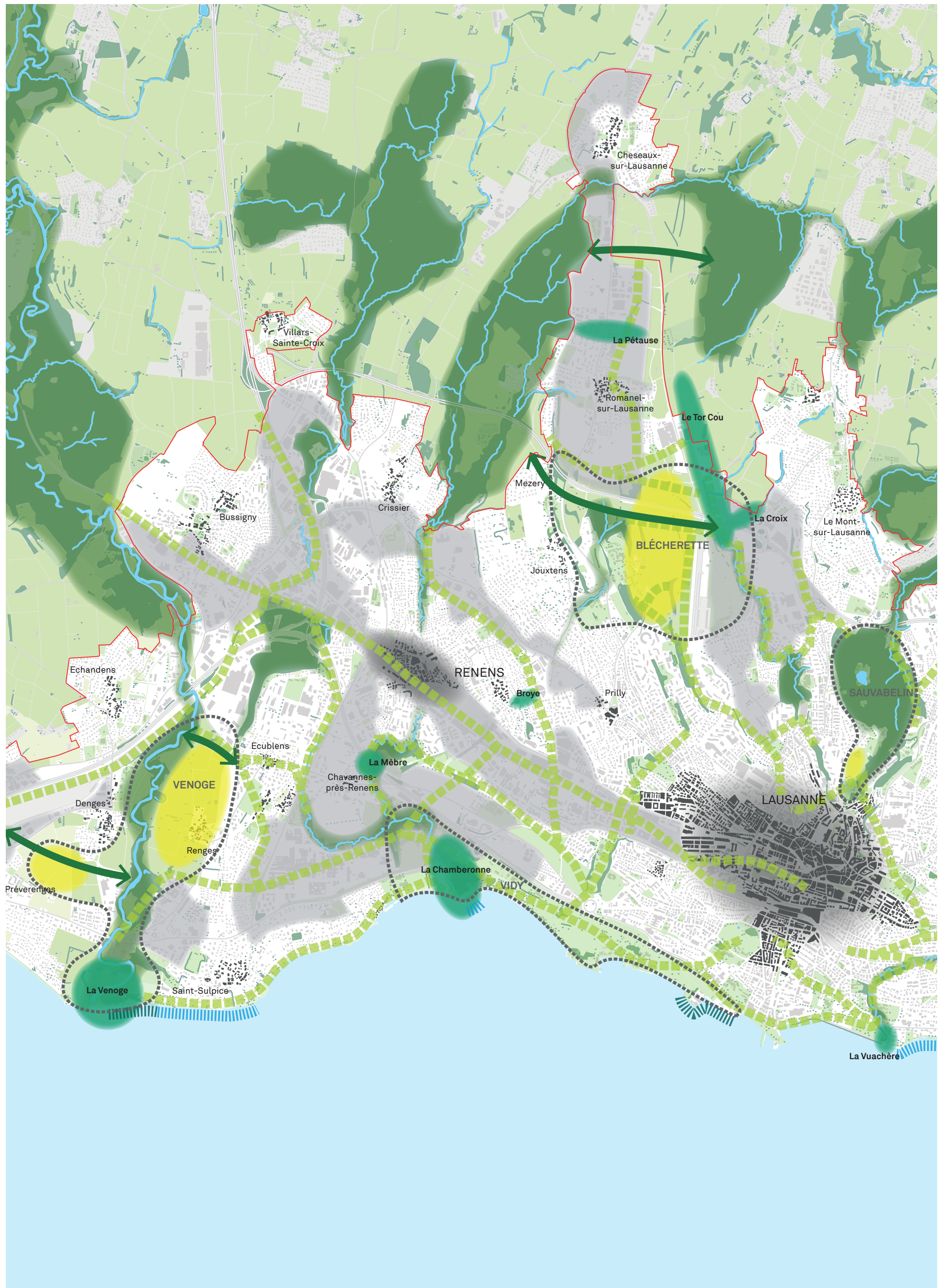
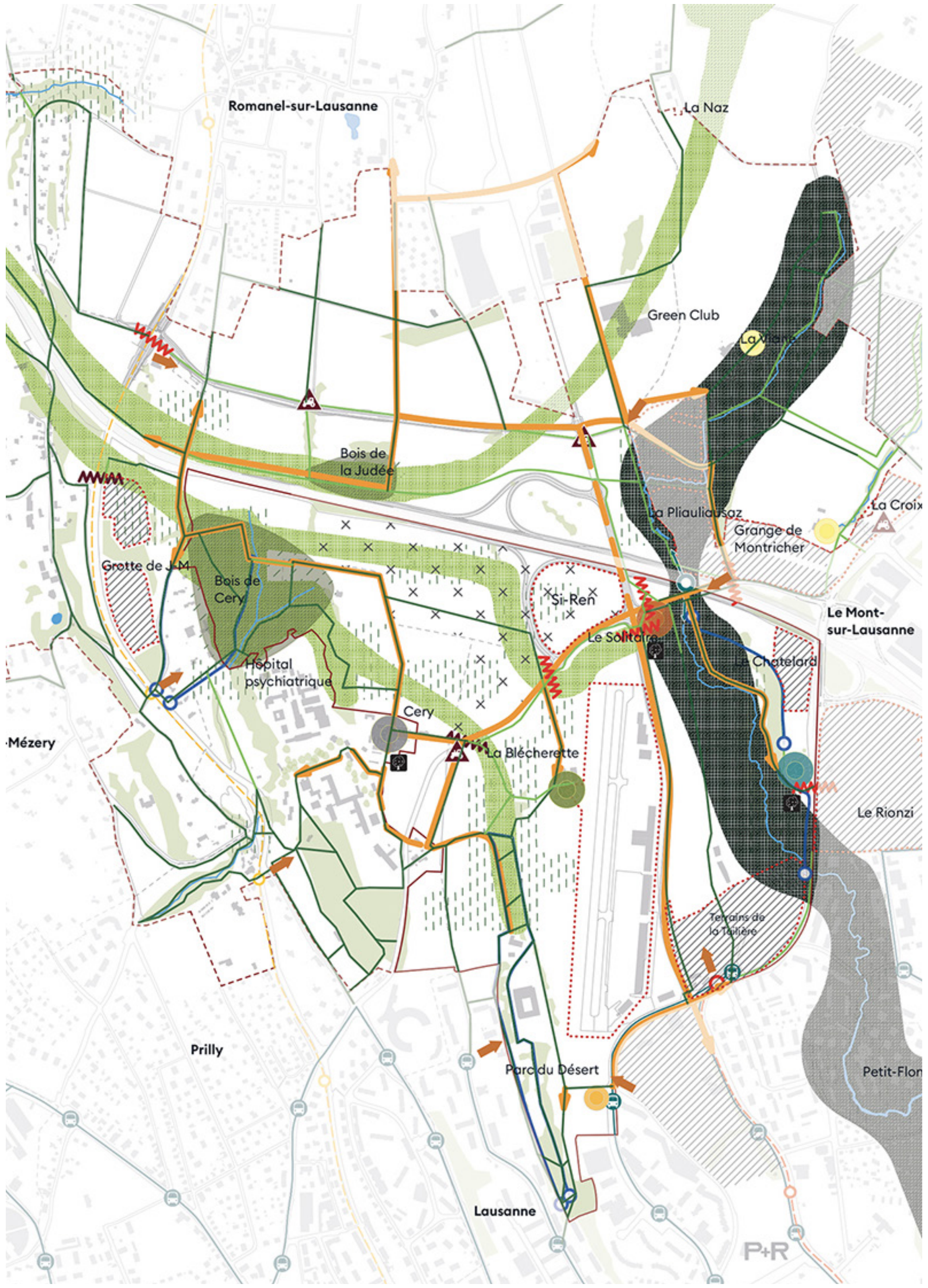


Swiss Federal Council, FOEN, Swiss National Soil Strategy for sustainable soil management, 2020



État de Vaud, DGTL, DGMR, Projet d'agglomération Lausanne-Morges (PALM) – Volet Environement,2016



Verzone Woods Architectes Sàrl & Repetti Sàrl, Étude Espace Blécherette, 2022

At the federal level, in coordination with the various federal, promote a change in the culture of urban planning and architecture, in the light of soils and their functions; in line with the "Soil Strategy" define and promote a holistic approach to urban soil functions, formulated in terms of co-benefits and ecosystem services; in coordination with the KoBo, support research follow up on implementation of innovative soil management solutions (Living Labs); initiate a debate on certain limiting aspects of the current legal framework.

At the level of cantonal planning and agglomeration project, develop cartographic tools as support for planning and management; collect and integrate soil diagnostics; take a critical look at urban density objectives and define targets for vegetation cover (greening index) and soil functions; identify possible incentives for surface de-sealing, soil regeneration and improvement of management practices on private land.

At the level of urban redevelopment projects, highlight good examples of urban redevelopment to promote de-sealing, less-armful construction techniques, soil reconstitution, diversification of vegetation covers; reflect soil protection and functions targets in "plans de quartier" and projects briefs; encourage the involvement of local actors to foster circular management of waste and information feedback.

Danke, grazie, merci

The final report will be availble on the FOEN website soon

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