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Designing with and for Vital Soil in Urban Areas

Healthy soils are increasingly recognized as critical infrastructures for urban resilience, climate adaptation, and sustainable development. Once regarded as inert substrates for construction, soils are now understood as dynamic, living systems that regulate water, sequester carbon, sustain biodiversity, and provide cultural and ecological value. This chapter explores the multifunctionality of soils in urban contexts, situating them at the intersection of climate adaptation, circularity and design practice. It traces current debates between instrumental framings of soil as a technical resource (e.g., carbon storage) and ecological framings that emphasize soils' relational, socio-ecological roles. The "sponge city" paradigm is highlighted as a key approach that operationalizes soil-sensitive design to enhance hydrological resilience, thermal comfort, and biodiversity. Building on these insights, this chapter presents the design methodology of PosadMaxwan, which positions soils as active partners in planning and urban design. This nature-based, interdisciplinary framework integrates soil vitality into iterative design processes, translating ambitions such as circularity, biodiversity, and climate adaptation into site-specific interventions. Moving from the concept of "vital soil" to a broader ethic of "soil care," this chapter argues for a paradigmatic shift in urbanism: one that foregrounds stewardship, cultural recognition, and professional practice attentive to soils as regenerative and relational systems. Such a shift enables the creation of multifunctional, adaptive, and resilient urban landscapes.

INTRODUCTION: SOIL MATTERS

Healthy soils are those capable of fully performing their natural functions. They ensure good food production by maintaining natural and sustainable fertility, while also protecting groundwater and food crops from excessive concentrations of pollutants and nutrients through their filtering capacity. Their well-structured composition regulates water management in both agricultural, urban and periurban areas, and they serve as an essential reservoir for carbon by storing CO_2 in organic components that enrich the soil. Healthy soils also sustain a rich and diverse ecosystem, which in turn supports these vital functions over the long term. In short, a healthy, naturally functioning Soil-Sediment-Water (SSW) system delivers a wide range of essential functions forming the foundation of nearly every societal transition. [1] Simultaneously, the soil subsurface provides capacity and space for human activities such as construction and energy storage. Especially in urban areas, it is increasingly recognised that this space claims need to be balanced with space for soil and water.

The attention to the fundamental importance of healthy soil has critically increased in the last decade in urbanism, urban disciplines and policies. EU and UN-Habitat international policies, such as the European Green Deal and the Roadmap to a Resource-Efficient Europe program, are increasingly focused on limiting land consumption and promoting

[1] See Brils J., Maring L., *A conceptual model for enabling sustainable management of soil-sediment-water ecosystems in support of European policy*, in "Aquatic Ecosystem Health & Management," 26, 2, 2023, pp. 63-79. https://doi.org/10.14321/aehm.026.02.063.

sustainable land use. [2] Already in the 1980s, Bernardo Secchi in his seminal *Progetto di suolo* (1986) [3] emphasized soil as an active agent rather than merely technical support to urban and territorial design. Today, this notion is expanded by the ecological transition, which places soil's living matter and ecosystemic functions at the centre of the urban debate. [4] In literature, the aforementioned values of soil are often framed in terms of ecosystem or geosystem services. Following this thinking, soil fulfils diverse and essential roles for the city: it supports food and biomass production, often externalized outside urban boundaries; [5] it provides physical ground for construction; it preserves historical traces as an archive of past human and ecological processes; it offers cultural, recreational, and aesthetic value; and it regulates climate, water cycles, and the living environment. [6] Yet when soil is degraded – through sealing, compaction, or contamination – it loses its capacity to provide food security, regulate climate, or buffer against flooding. [7]

In urban contexts, these pressures are particularly acute. Cities place multiple and often conflicting demands on limited soil resources: infrastructure, housing, utilities, and green spaces all compete for space and function. Without careful stewardship, the very foundation that supports sustainable urban life is eroded. Recognising soil as a vital and irreplaceable resource means rethinking how we design and manage our urban environments. Protecting and regenerating soil vitality must therefore become a central concern of urbanism and planning – not only for agriculture or conservation, but for building healthier, more resilient cities. Hence, how can soil be understood as a critical regenerative resource and system through which designing future urban projects? This paper explores the importance of vital soil in urban contexts. For this design context, we draw on *Designing with and for Vital Soil in Urban Areas*, a handbook by PosadMaxwan from 2024 that presents a nature-based, integrated approach to urban design. The handbook positions soil as both a critical resource and a regenerative system, encouraging designers to collaborate with soil scientists, ecologists, and hydrologists to create circular and regenerative public spaces.

[2] See United Nations, *Resolution adopted by the General Assembly on 20 December 2013: International Year of Soils, 2015 (A/RES/68/232)*, United Nations, New York 2013.
[3] See Secchi B., *Progetto di suolo*, Casabella, 520-521, 1986, pp. 19-23.
[4] Viganò P., Guenat. C., *Our Common Soil*, in "Oase," 110, 2022, pp. 53-66.
[5] See Mantziaras P., Viganò P. (edited by), *Le sol des villes: Ressource et projet*, MétisPresses, Genève 2016.
[6] See Viganò P., Guenat C., *op. cit.*
[7] Cavalieri C., *Soil: From Conservation to Modification 'No Net Land Taken' in Flanders*, in Santoso J., Brigita M., Suryadjaja R., Ayu Rahma Lestari N., "Beyond resilience. Towards a more integrated and inclusive urban design," International Forum on Urbanism, Faculty of Architecture TU Delft 2019, pp 306-313.

SETTING THE BASIS, LIVING SOILS IN TIMES OF CLIMATE CHANGE

In 2023, global temperatures reached unprecedented levels, marking the hottest year on record. [8] Most urban areas remain inadequately prepared to cope with rising temperatures, posing significant risks to the health and well-being of both human and non-human inhabitants. [9] Urban infrastructures were primarily designed to accommodate the relatively stable climatic conditions of the 20th century; however, accelerating climatic variability in the 21st century is increasingly revealing their functional limitations. [10] Given the impracticality of large-scale urban reconstruction, exploring adaptive strategies within existing frameworks has become essential. In this context, soil and its subsurface are increasingly recognized as critical interfaces, yet they are often framed in reductionist ways. Rising temperatures, altered rainfall regimes, and the intensification of droughts and floods physically, chemically, and biologically transform soil conditions. These transformations are not only biophysical processes but are also mediated by discourses that shape how soils are understood and governed. Competing narratives present soils either as technical instruments for carbon storage or as complex ecological systems that sustain multiple services. One dominant discourse positions soil as a carbon sink with substantial potential for mitigating greenhouse gas emissions through sequestration. This framing casts soils as

[8] See Intergovernmental Panel on Climate Change (IPCC), *Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva 2023.
[9] World Health Organization (WHO), *Urban green spaces and health: A review of evidence*, WHO Regional Office for Europe, Copenhagen 2016, available at: https://www.who.int/europe/publications/i/item/WHO-EURO-2016-3352-43111-60341.
[10] See United Nations Environment Programme (UNEP), *Adaptation gap report 2021: The gathering storm*. UNEP, Nairobi 2021; Intergovernmental Panel on Climate Change (IPCC), *op. cit.*

manageable reservoirs that can be engineered to contribute to global climate targets. However, empirical studies show that sequestration potential is constrained by saturation effects and the impermanence of stored carbon. [11] Overreliance on this mitigation narrative risks obscuring the multifunctional roles of soils, including nutrient cycling, water regulation, and biodiversity support. By contrast, ecological framings highlight soils as living systems embedded within wider socio-ecological networks. These framings point toward resilience and adaptation, emphasizing practices that maintain soil health under climate stress. At the biophysical level, the interaction between climate variability and soil dynamics is well documented. Variability in precipitation and drought has been shown to affect soil moisture regimes, producing complex feedbacks that influence water availability and plant growth. [12] These findings reinforce the view that soil is an active participant in climate systems rather than a passive background. A discursive emphasis on soil multifunctionality resonates with such empirical evidence, suggesting the need to move beyond singular framings of soil as a carbon storage medium.

In urban contexts, the discussion above gains increased importance. Cities impose numerous and often conflicting demands on limited soil resources: infrastructure, utilities, housing, and green spaces all compete for space and function. Without careful management, the very foundation supporting sustainable urban life is at risk. Enhancing soil permeability provides a mechanism for reducing stormwater peak flows and buffering the impacts of intense rainfall events, thereby strengthening the resilience of urban environments under climatic uncertainty. [13] Such "source-control measures" intervene early in the water cycle – through infiltration zones, permeable surfaces, or rainwater reuse systems – and are increasingly recognized as more effective and sustainable than end-of-pipe solutions. [14] Climate change also worsens the urban heat island (UHI) effect, where cities become

[11] See Schils R., Dekker C., Oenema J., Hilhorst G., Wagenaar J.P., Verloop K., *Measuring and modeling soil carbon changes on Dutch dairy farms,* in "Land," 14, 4, 874, 2025.

[12] See Teuling A.J., Hupet F., Uijlenhoet R., Troch P.A., *Climate variability effects on spatial soil moisture dynamics,* in "Geophysical Research Letters," 34, 6, L06406, 2007.

[13] See Kabisch N., Korn H., Stadler J., Bonn A. (edited by), *Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy and practice,* Spinger, Cham 2017.

significantly warmer than surrounding rural areas. This exacerbates heat stress, increases energy demand for cooling, and public health risks. Urban design can help counteract these effects through strategies such as integrating green spaces, enhancing ventilation, and adopting reflective construction materials. [15] Soils also play a crucial role by supporting vegetation that cools cities through evapotranspiration while providing ecological connectivity and habitat. Furthermore, rising temperatures and changing precipitation patterns have a significant impact on urban biodiversity and ecosystems. Soils that function as living systems help sustain local flora and fauna, contributing to ecological resilience. Integrating biophilic design elements – such as green roofs, urban forests, and wildlife corridors – further enhances these benefits. Informal green spaces, often overlooked, provide crucial cultural ecosystem services, particularly in marginalised neighbourhoods where they support recreation, social interaction, and mental well-being. [16]Taken together, these perspectives expose a tension between instrumental narratives, which treat soil as a resource to be optimised, and ecological narratives, which highlight soils as dynamic and living systems. The balance between these systems has important implications for research priorities, policy tools, and land-use decisions. Recognising soils as multifunctional and relational opens paths for adaptation strategies that acknowledge limits to carbon sequestration while promoting practices that boost resilience.

At the policy level, the European Environment Agency [17] has documented the increasing adoption of adaptation measures – such as green spaces, permeable surfaces, and tree canopies – by European cities to address urban overheating. Similarly, the EU Climate-ADAPT platform highlights

[14] See De Bondt K., *De vergeten connecties tussen grondwater en stedelijk waterbeheer: Stabiele waterisotopen (δ18O, δD) en de "Urban Hydrologic Landscapes" methode toegepast op Brussel,* Doctoral Dissertation Vrije Universiteit Brussel, Brussel 2017; Ranzato M., (edited by), *Water vs. urban scape: Exploring integrated water-urban arrangements,* JOVIS, Berlin 2017.

[15] See Kleerekoper L., *Urban climate design: Improving thermal comfort in Dutch neighborhoods,* Doctoral Dissertation, Delft University of Technology, Delft 2016.

[16] See Luo S., Naghibi M., Patuano A., van Leeuwen E., *Cultural ecosystem services of informal green spaces: Insights from deprived urban neighborhoods,* in "Local Environment," pp. 1–21. https://doi.org/10.1080/13549839.2025.2533130.

[17] See European Environment Agency, *Urban adaptation in Europe: What works?,* EEA Report 14/2023, available at: https://www.eea.europa.eu/en/analysis/publications/urban-adaptation-in-europe-what-works.

urban overheating and associated adaptation measures as critical strategies for mitigating heat-related risks in European contexts. [18] Integrating these measures with soil-sensitive design highlights how soils can also be reimagined not only as tools for mitigation but as foundational elements of more sustainable and resilient urban futures.

Bringing these contexts together reveals how soils occupy a pivotal position at the intersection of climate mitigation, adaptation, and urban resilience. While the debate between instrumental and ecological framings highlights the contested ways in which soils are understood and governed, their multifunctional role in regulating water, supporting vegetation, and buffering climatic extremes is increasingly acknowledged in both science and policy. This recognition fosters integrative design frameworks that embed soils and green infrastructure within urban planning. Among these, the sponge city paradigm became a particularly influential approach, translating the multifunctionality of soils into concrete strategies for managing stormwater, reducing heat stress, and enhancing biodiversity in dense urban environments.

SOIL MATTER IN THE SPONGE CITY APPROACH

Approximately a decade ago, many cities adopted urban greening primarily as a strategy to mitigate pluvial flooding associated with climate change. [19] More recently, the cooling capacity of green infrastructure has become an integral component of urban climate adaptation strategies. [20] Among these measures, tree planting has emerged as a widely favoured intervention due to its multifunctional benefits: carbon sequestration, air pollution reduction, mitigation of the urban heat island effect, alleviation of heat stress, enhancement of biodiversity, and promotion of human health and well-being. [21] Aligned with Nature-Based Solutions

[18] See World Bank, *Urban Overheating & Adaptation Measures: An analysis at EU, national, and local level*, World Bank, published in Climate-ADAPT, Washington, D.C. 2024.
[19] See Kabisch N., Korn H., Stadler J., Bonn A., *op. cit.*
[20] See United Nations Environment Programme (UNEP), *op. cit.*
[21] See Bowler D.E., Buyung-Ali L., Knight T.M., Pullin A.S., Urban greening to cool towns and cities: A systematic review of the empirical evidence, in “Landscape and Urban Planning,” 97, 3, 2010, pp. 147–155; World Health Organization (WHO), Urban green spaces and health: A review of evidence, WHO Regional Office for Europe, Copenhagen 2016.

(NBS) and Green Infrastructure (GI) approaches, improving soil permeability facilitates stormwater infiltration, mitigates peak discharge during extreme precipitation, and reduces flood risks in urban areas. [22] Beyond hydrological regulation, urban soils sustain vegetation growth, including trees and understory plant communities, that generate shade, reduce the UHI effect, and alleviate heat stress during periods of extreme heat. [23] Globally, healthy soils store approximately three times more carbon than the atmosphere, making them indispensable for regulating the carbon cycle, ensuring food security, and sustaining ecosystem services such as water regulation and biodiversity conservation. [24] Yet soil degradation driven by unsustainable land-use practices and exacerbated by climate change threatens these functions, creating dangerous feedback loops that accelerate ecosystem decline and warming. [25] These mechanisms converge in the “sponge city” paradigm, which reframes urban landscapes from purely engineered infrastructure toward hybrid socio-ecological systems capable of absorbing, storing, and reusing rainwater. Rooted in NBS principles, sponge cities emphasize the multifunctional role of soils and vegetated systems in enhancing hydrological resilience, mitigating urban heat islands, and supporting ecosystem services under climatic uncertainty. [26] Scientific assessments highlight its efficacy in strengthening

[22] See Raymond C.M., Frantzeskaki N., Kabisch N., Berry P., Breil M., Nita M.R., Geneletti D., Calfapietra C., A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas, in “Environmental Science & Policy,” 77, 15–24, 2017.
[23] See Bowler D.E., Buyung-Ali L., Knight T.M., Pullin A.S., *op. cit.*
[24] See Intergovernmental Panel on Climate Change (IPCC), *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. IPCC, Geneva 2019; Food and Agriculture Organization of the United Nations (FAO), *Soil organic carbon: The hidden potential*. FAO, Rome 2017. https://openknowledge.fao.org/server/api/core/bitstreams/b382a255-5bd5-4656-a8cd-e30fff1a8bfe/content.
[25] See Montanarella L., Pennock, D.J., McKenzie N., Badraoui M., Chude V., Baptista I., Mamo T., Yemefack M., Singh Aulakh M., Yagi K., Hong, S.Y., Vijarnsorn P., Zhang, G.L., Arrouays D., Black H., Krasilnikov P., Sobocká J., Alegre J., Henriquez, C.R., … Vargas R., *World’s soils are under threat*, in “Soil,” 2, 1, pp. 79–82, 2016. https://doi.org/10.5194/soil-2-79-2016.
[26] See Li H., Ding L., Ren M., Li C., Wang H., *Sponge city construction in China: A Survey of the Challenges and Opportunities* , in “Water,” 9, 594, pp. 1–11, 2017. https://doi.org/10.3390/w9090594; United Nations Environment Programme (UNEP), *Beating the heat: A sustainable cooling handbook for cities*. UNEP, Nairobi 2021; Qi Y., Chan, F.K.S., Thorne C., O’Donnell E., Quagliolo C., Comino E., Pezzoli A., Li L., Griffiths J., Sang Y., et al. *Addressing Challenges of Urban Water Management in Chinese Sponge Cities via Nature-Based Solutions*, in “Water,” 12, 2788, 2020. https://doi.org/10.3390/w12102788.

urban climate resilience and delivering co-benefits for health and biodiversity. [27]

European cities are increasingly adopting principles of the sponge city concept. Copenhagen has implemented rain gardens and sustainable urban drainage systems in Sankt Kjelds Plads (2019) and redesigned Enghaveparken (2014) to retain 22,600 m³ of rainwater. Berlin is expanding green roofs, permeable pavements, and wetlands to reduce flood risks. Vienna integrates multifunctional parks and porous surfaces to alleviate flooding and heat stress. Amsterdam is pioneering "blue green" roofs through the Resilio project, covering over 9,000 m² of rooftops with systems that store and release rainwater. Pontevedra has restored the Gafos River and created floodable parks as part of a broader strategy for sustainable water management. These examples illustrate how the sponge city approach integrates soil-sensitive design with green infrastructure to enhance climate resilience. [28]

Crucially, the success of sponge city strategies depends on local soil conditions. Research in Amsterdam and other European cities reveals that soil texture, compaction, and groundwater levels significantly impact infiltration and storage, thereby influencing the effectiveness of green infrastructure in mitigating floods and heat. [29] These insights challenge the notion of sponge cities as universally applicable models, instead emphasizing the need to tailor interventions to local soil properties and hydrological dynamics. Integrating soil quality into climate adaptation strategies enables the development of multifunctional landscapes that extend beyond flood control, simultaneously strengthening resilience to extreme weather, reducing heat stress, and supporting biodiversity. [30]

By prioritising soil at the centre of climate adaptation, the sponge city paradigm emphasises a broader discursive shift: from viewing soils as passive substrates to recognising them as dynamic systems that influence the success of urban resilience strategies. This perspective highlights the interdependence of soil health, urban design, and climate adaptation, offering a model particularly pertinent in Europe, where dense urbanisation coincides with heightened climate risks. [31]

WHY CARE ABOUT SOIL IN URBAN AREAS?

Healthy soils are thus key to building resilient and sustainable cities. Integrating them into urban design not only addresses climate change but also enhances biodiversity, reduces resource consumption, and secures livable conditions for future generations. The evidence reviewed shows that soils maintaining their natural vitality perform multiple indispensable roles: sustaining fertility for food production, regulating hydrological cycles, filtering pollutants, and serving as long-term carbon reservoirs. In cities, however, soils face intensified pressures – including sealing, compaction, and contamination – that erode their multifunctionality and undermine their capacity to sustain both ecosystems and societies. Recent ecological transitions have reframed soils from inert substrates for construction toward dynamic, living systems central to adaptation and sustainable development. This discursive shift aligns with international agendas such as the European Green Deal and the UN's *Roadmap to a Resource-Efficient Europe*, which emphasise limiting land consumption and promoting regenerative land-use practices. Integrating soil health into urban planning is becoming increasingly urgent due to accelerating climate variability. Healthy soils mediate critical adaptation functions: enhancing permeability reduces flood risks by attenuating stormwater peaks; sustaining vegetation

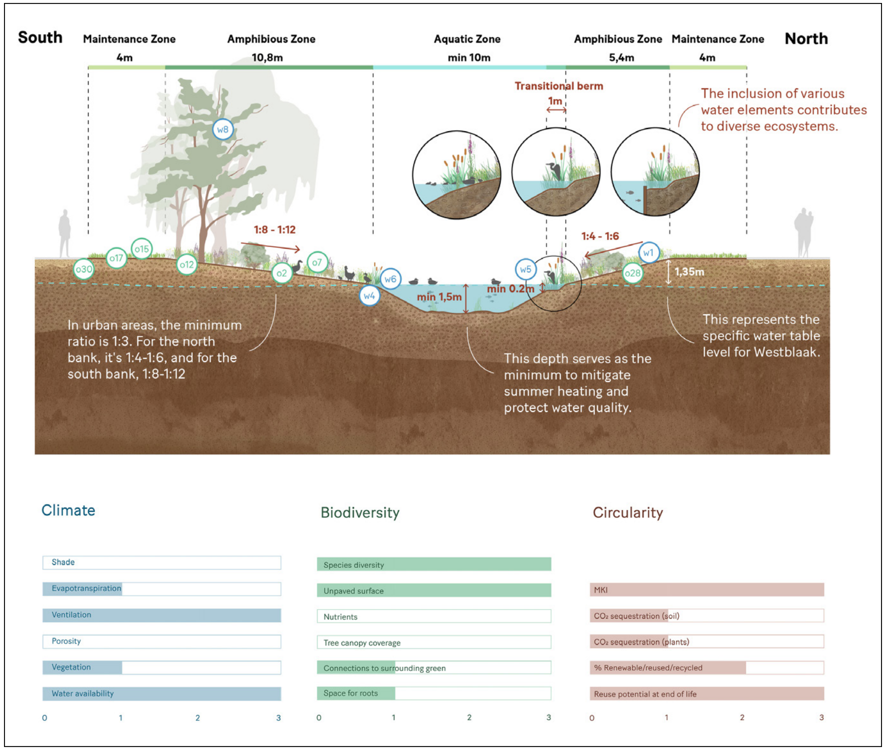
[27] See Revi A., Satterthwaite D.E., Aragón-Durand F., Corfee-Morlot J., Kiunsi R.B., Pelling M., Robert D.C., Solecki W., *Urban areas,* in "Climate change 2014: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change," Cambridge University Press, Cambridge 2014; Intergovernmental Panel on Climate Change (IPCC), *Climate change 2022: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Chapter 13: Europe,* Cambridge University Press, Cambridge 2022; Intergovernmental Panel on Climate Change (IPCC), *Climate change 2022: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Chapter 6: Cities, settlements and key infrastructure,* Cambridge University Press, Cambridge 2022.

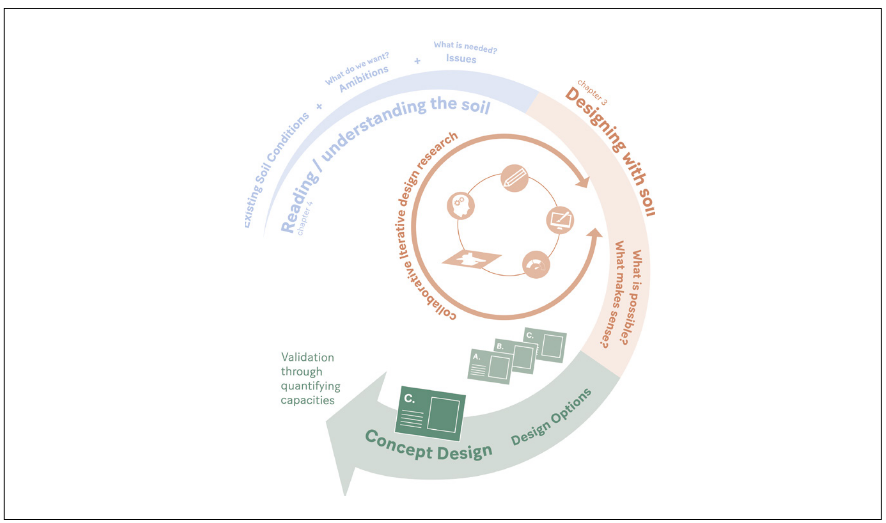
[28] See World Bank, *Urban Overheating & Adaptation Measures: An analysis at EU, national, and local level.* Published in Climate-ADAPT, World Bank, Washington D.C July 4, 2024.

[29] See Delibas M., Tezer A., Bacchin T.K., *Towards embedding soil ecosystem services in spatial planning,* in "Cities," 113, 103150, 2021.

[30] See Tang A.M., Hughes P.N., Dijkstra T.A., Askarinejad A., Brenčič M., Cui Y.J., … Van Beek V., *Atmosphere-vegetation-soil interactions in a climate change context: Impact of changing conditions on engineered transport infrastructure slopes in Europe,* in "Quarterly Journal of Engineering Geology and Hydrogeology," 51, 2, pp. 156-168, 2018.

[31] Schils R., Dekker C., Oenema J., Hilhorst G., Wagenaar J.P., Verloop K., *op. cit.*





[Fig. 1] PosadMaxwan, Specific Measure for the vital soil, incorporating rules of thumb and a potential combination with other measures.
[Fig. 2] PosadMaxwan, Design Process. Designing with/for soil begins with a thorough understanding of the soil's conditions, followed by iterative design research to inform design options. The scheme captures this schematic process.

alleviates the urban heat island effect; and supporting biodiversity strengthens ecosystem resilience. The sponge city paradigm exemplifies this approach, embedding soil quality within broader frameworks of nature-based solutions to create multifunctional landscapes that combine hydrological regulation, thermal comfort, and ecological co-benefits.

Thus, recognizing soils as active and regenerative infrastructures requires a paradigmatic shift in urban design and planning. So, while sections 2 and 3 highlighted why soil is central to urban resilience, the question remains: how can these insights be translated into practice? In response, design offices have begun to experiment with methods that treat soil as an active design partner. One such approach is the methodology of PosadMaxwan, which integrates soil vitality into concrete planning and design processes.

DESIGNING WITH SOIL, A PERSPECTIVE BY POSADMAXWAN

Building on the recognised importance of vital soil as a foundation for urban resilience, this chapter introduces a practical design methodology for integrating soils into urban planning. Developed by PosadMaxwan in 2024, the approach advances a nature-based, integrated framework for circular and regenerative public spaces. Rather than treating soil as a passive substrate, the methodology reframes it as a dynamic and living system that must be actively designed with and for. By providing a structured process, it enables urban designers, planners, and ecologists to translate abstract ambitions – such as climate adaptation, biodiversity enhancement, and circularity – into site-specific interventions. In doing so, it bridges theory and practice, providing both a conceptual reorientation and a practical toolkit for the development of multifunctional, resilient, and regenerative urban landscapes (Fig.2).

A NATURE-BASED AND INTEGRATED DESIGN APPROACH

At the core of the PosadMaxwan method lies a nature-based design approach, in which the functions of water, soil, and subsurface systems are positioned as leading principles in spatial planning. This approach is fundamentally interdisciplinary, requiring collaboration across soil science, hydrology, ecology, and landscape architecture. Such integration moves beyond siloed practices – where engineers manage subsurface utilities and designers focus on surface form [32] – toward a holistic model that recognizes the interdependence of above-ground and below-ground systems. This orientation aligns with broader academic and policy calls for NBS, defined as actions that protect, manage, and restore ecosystems to address societal challenges while providing benefits for human well-being and biodiversity. [33] By treating the urban landscape as a cohesive socio-ecological system, the methodology seeks to develop solutions that are both environmentally restorative and socially equitable.

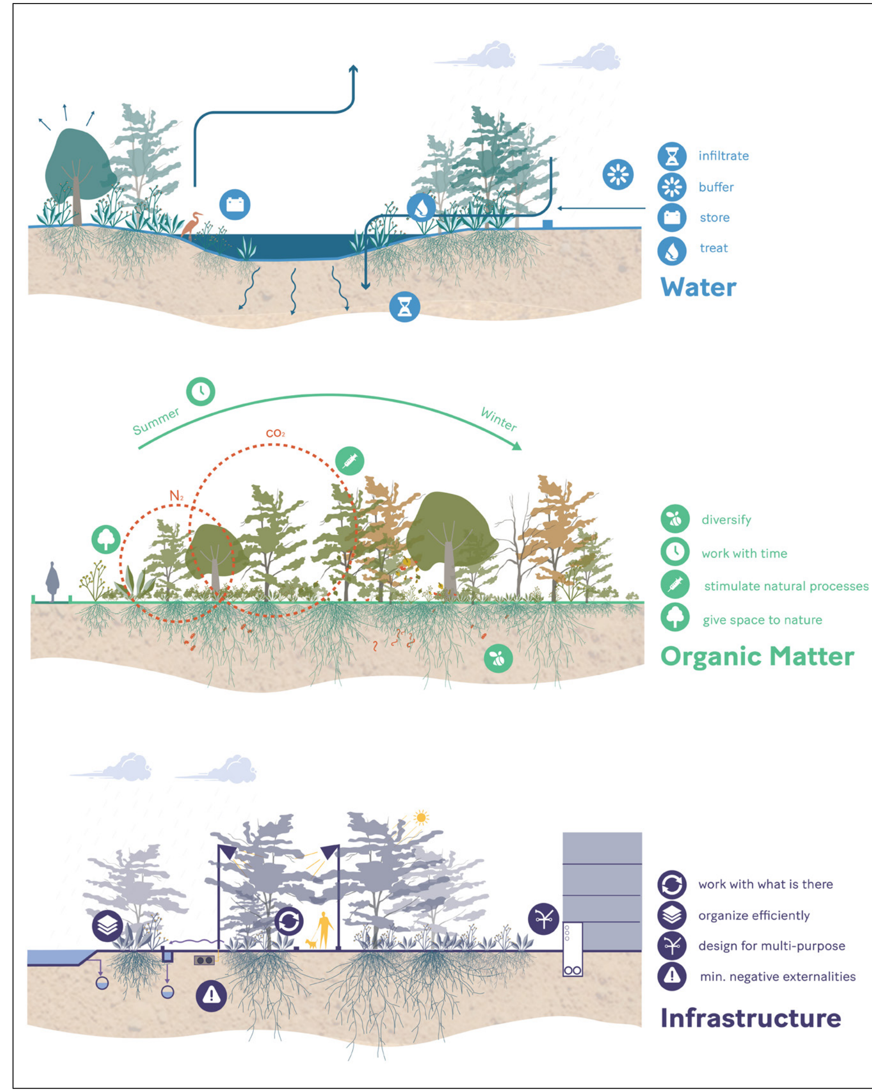
DESIGN PRINCIPLES FOR VITAL SOIL

To address the complexity of designing with living systems, the methodology is structured around three interrelated components of urban soil systems: water, organic material, and subsurface infrastructure. Each component is articulated through design principles that guide decision-making and ensure ecological and technical considerations are integrated into urban practice (Fig. 3).

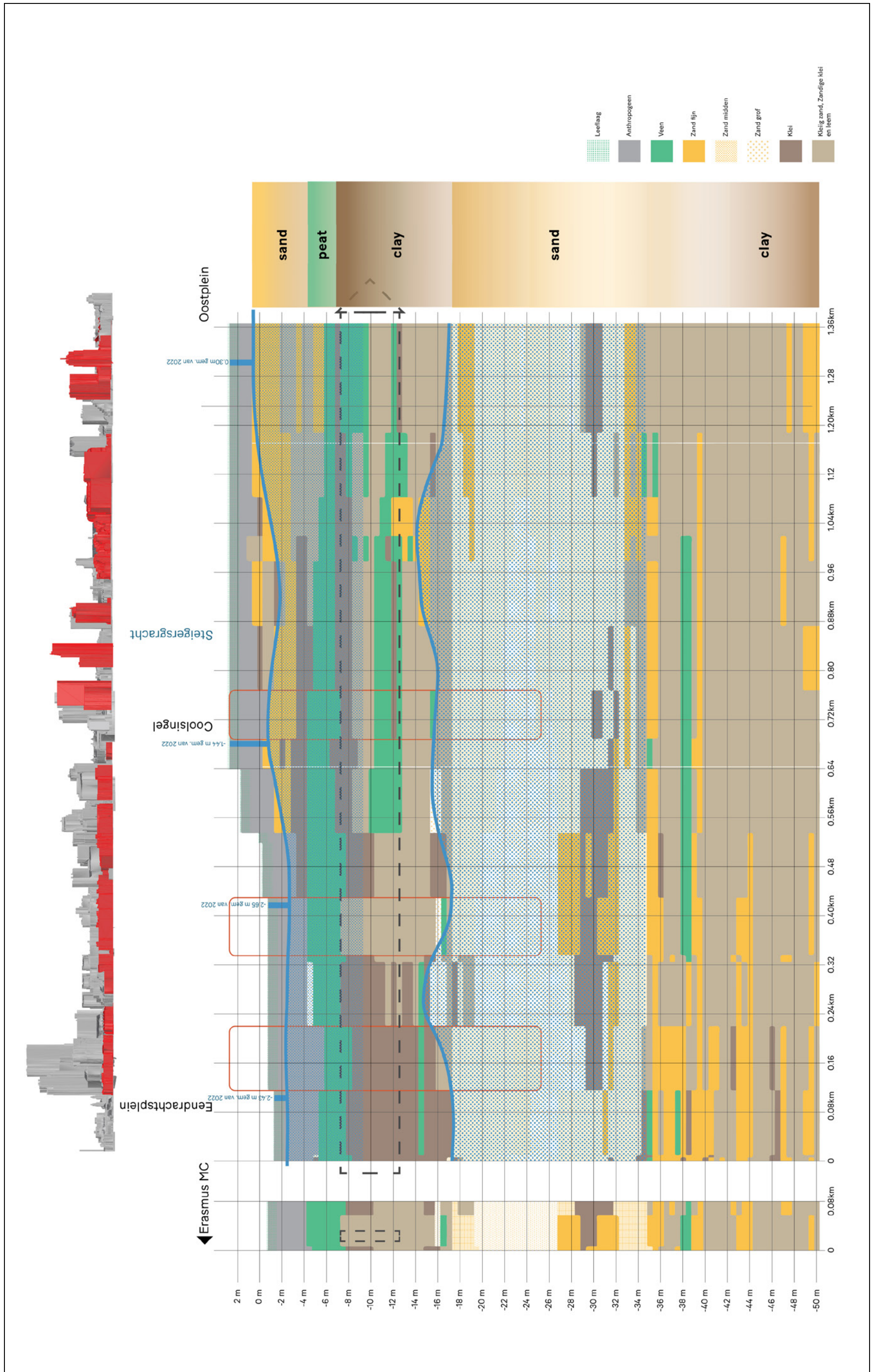
Water. This component foregrounds the transition from conventional rapid-drainage models to the ecologically resilient sponge city approach (see Section 1.3). The guiding principle is to enable infiltration, buffering, and storage through soil-sensitive designs, such as rain gardens, which retain water locally. Complementary to this is the principle of treating runoff on-site, using soil and vegetation to filter pollutants before water enters broader municipal systems.

Organic material. Soils are positioned as dynamic, living ecosystems. Three principles shape this perspective: (1) increase biodiversity by designing habitats for multiple species; (2) stimulate natural processes, such as decomposition, that enrich soil over time; and (3) acknowledge ecological temporality, allowing systems to evolve through succession rather than imposing static, maintenance-heavy designs.

[32] See Hooimeijer F.L., Tummers-Mueller L.C., *BALANCE 4P – Balancing decisions for urban brownfield regeneration – people, planet, profit and processes*, TU Delft Repository, Delft 2015.
[33] See Cohen-Shacham E., Janzen C., Maginnis S., Walters G., (edited by), *Nature-based solutions to address global societal challenges*, IUCN, Gland 2016.



[Fig. 3] PosadMaxwan, Design Principles. To simplify the complexity of designing with/for soil, we look at three components that interface with soil: water, organic material, and infrastructure.



[Fig. 4] PosadMaxwan, Westblaak Rotterdam. *The schematic section below shows the subsoil upto 50m deep. The section is based on the open data from the GeoTOP model of the BRO. GeoTOP is a 3D model that represents the subsurface up to a maximum of 50 meters below sea level in blocks (voxels) of 100 × 100 × 0.5 metres.*

Infrastructure. The subsurface is understood as the "engine room" of the city – crowded yet indispensable. Principles here include: (1) efficient organization of utilities (e.g., multi-utility tunnels) to preserve soil volumes for roots and hydrological functions; (2) embedding circularity, by repurposing obsolete infrastructure (e.g., disused pipes as root conduits); and (3) reducing external impacts such as compaction or pollution by differentiating maintenance paths from no-walk infiltration zones.

These principles are operationalized in the PosadMaxwan handbook, which catalogues specific design interventions and a place-based methodology. The test of the design principles and interventions is operationalized through an iterative design process, structured around five key stages. This process is deliberately conceived to ensure that solutions are not generic but firmly rooted in the specific context of the site as well as the overarching ambitions of the project. By combining contextual analysis with interdisciplinary collaboration, the methodology foregrounds adaptiveness and critical reflection, qualities essential for working with dynamic living systems.

1. Assessing Soil Conditions and Defining Ambitions begins with a comprehensive analysis of the existing context, moving beyond surface-level observations to a deep reading of the soil. This involves spatial and systems analysis of soil composition, water flows, existing ecosystems, and underground infrastructure. This baseline understanding is then juxtaposed with the project's key ambitions, which could range from maximizing climate adaptation and biodiversity to enhancing circularity.
2. Apply Iterative Interdisciplinary Design, starting with a "research by design" exercise that clearly defines the problem. Instead of aiming for a single perfect solution, this phase involves repeatedly exploring how various design interventions can meet the stated goals. This collaborative process includes ongoing input from the interdisciplinary team to refine and adjust design choices.
3. Developing Extreme Scenarios and Measures is intended to expand the design space by deliberately exaggerating certain ambitions. For example, designing for maximum biodiversity or maximum water retention provides insight into the bandwidth of possible outcomes. This approach not only sharpens awareness of trade-offs

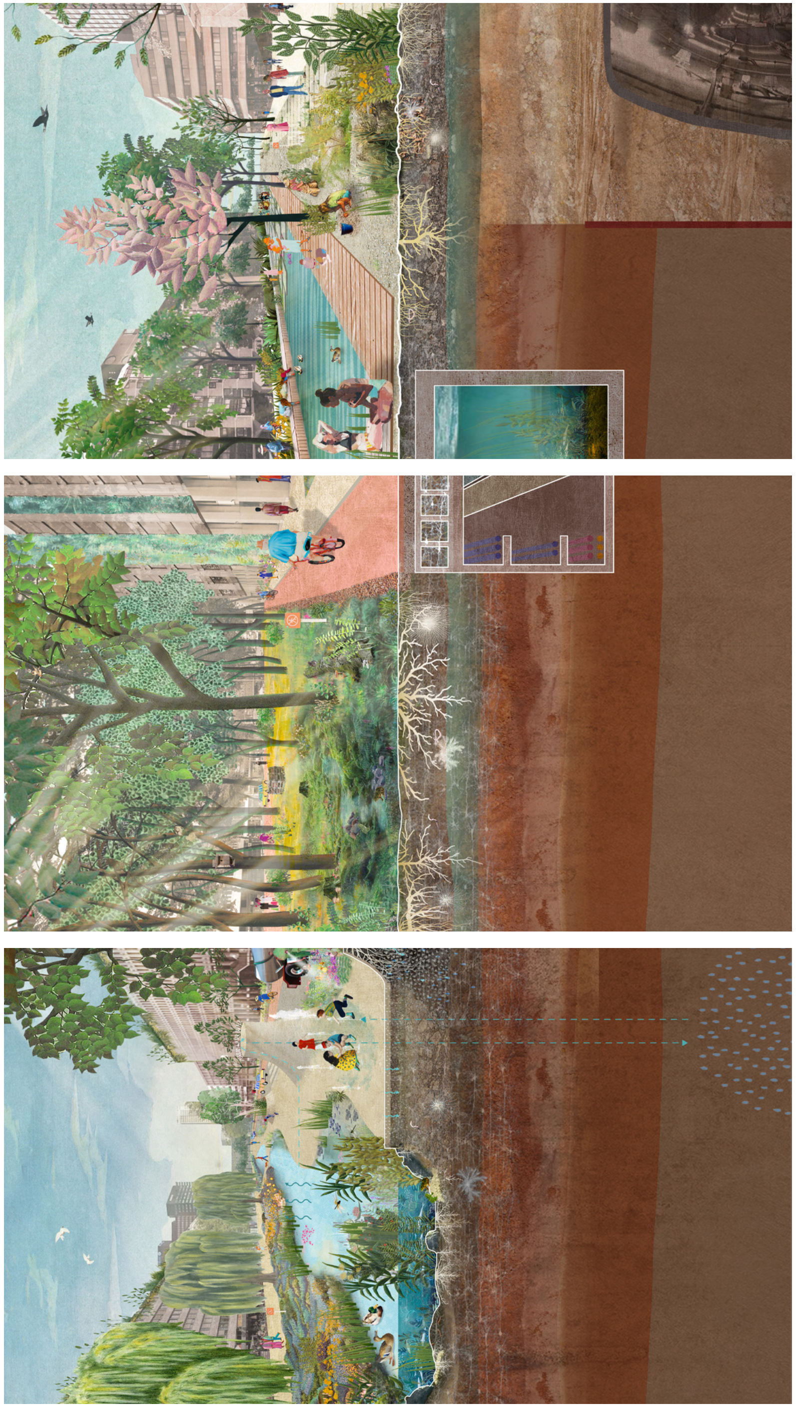
between competing goals but also enables the identification of synergies across ecological, social, and infrastructural aspects.

4. Validating Solutions using Systems Analysis shifts the focus from exploration to evaluation. Here, proposed design concepts were assessed not only for their aesthetic and functional qualities but also for their systemic performance. This included quantifying the capacities of the new design – for instance, the volume of water it can buffer, the potential increase in biomass, or the reduction in material waste. For the municipal client, this step was especially important: they stressed the need for "numbers" to support which measures should be prioritised where, and to justify these choices against other spatial claims on public space.
5. Developing a Preferred Design Scenario synthesizes the findings from previous iterations. By combining tested interventions, quantified performances, and insights gained from extreme scenarios, a contextually grounded and ambition-driven design proposal emerges. Importantly, the preferred scenario is not positioned as a fixed endpoint, but as a provisional synthesis that remains open to further adjustment as conditions evolve (Fig. 5).

Beyond guiding a specific project, this iterative process itself is an important outcome. Its structured yet flexible framework offers a transferable approach to designing with and for soils, providing urban practitioners and municipalities with a replicable means of aligning ecological processes, infrastructural demands, and social ambitions effectively (Fig. 4).

A REFLECTION ON THE DESIGN WITH SOIL APPROACH

The design process culminates in a site-specific design that integrates a prioritised set of measures aligned to the project's primary ambitions. Rather than prescribing a fixed solution, the methodology employs scenarios – Maximizing Climate Adaptation, Maximizing Biodiversity, and Maximizing Circularity – these scenarios provide designers and stakeholders with a structured means of articulating priorities, while simultaneously expanding the design imagination by making visible the range of possible futures. The final design outcome is typically a synthesis of measures across scenarios, generating



[Fig. 5] Scenario of an alternative future of Westblaak. Maximizing CImate Adaptation, B. Maximizing Biodiversity, C. Maximizing Circularity (source: PosadMaxwan).

a multifunctional, resilient, and regenerative landscape. In this way, soil-centred design transcends disciplinary silos, integrating hydrological resilience, ecological vitality, and material circularity into a coherent urban strategy. Alongside methodological synthesis, the project also explored new visualizations of soil. Conventional architectural drawings often obscure the living, temporal qualities of soil; alternative representations were developed to communicate these dynamics, fostering what the team terms "Soil Care." These visualizations serve not only as technical tools but also as cultural instruments, cultivating stewardship and attentiveness among designers, policymakers, and stakeholders. Thus, the PosadMaxwan methodology does more than generate site-specific interventions: it contributes to a broader professional and cultural shift toward acknowledging soil as an active agent in urban resilience and design.

CONCLUSION: SHIFTING FROM VITAL SOIL TO SOIL CARE

This chapter has highlighted that soils in urban contexts are neither inert backdrops nor merely technical infrastructures, but vital, living systems whose multifunctionality underpins ecological resilience, climate adaptation, and urban livability. [34] As climate pressures intensify and urban demands on subsurface resources multiply, the recognition of soils as regenerative infrastructures becomes indispensable. [35] Yet, this recognition must extend beyond conceptual acknowledgement of *vital soil* toward an ethic and design practice and governance of *soil care*.The notion of vital soil provides a critical conceptual reorientation, emphasizing soil's multifunctional roles in regulating water, sequestering carbon, sustaining biodiversity, and supporting socio-cultural values. [36] However, treating soil vitality as a fixed property risks obscuring the relational and temporal dimensions of soils as dynamic systems that are continuously shaped by ecological processes and human interventions. [37] By contrast, the emerging framework of *soil care* foregrounds responsibility, attentiveness, and stewardship. It implies a cultural and professional shift in which designers, planners, policymakers, and citizens recognize their active role in maintaining and regenerating soils as part of the urban commons. [38]

The methodological design approach innovations exemplified by PosadMaxwan demonstrate how such a shift can be operationalized in design practice of urban territories. Their interdisciplinary, nature-based approach translates abstract ambitions into place-specific design practices that integrate hydrological resilience, ecological vitality, and circular use of subsurface resources. Importantly, the design process is iterative, adaptive, and open-ended, acknowledging the living temporality of soils and cultivating a mode of practice that is less about control than about care. [39] Shifting from vital soil to soil care thus signals a paradigmatic transition in urbanism: from treating soils as background conditions to engaging them as partners in shaping resilient, multifunctional, and regenerative urban landscapes. This transition requires not only technical innovation but also cultural transformation – new forms of visualization, governance, and professional practice that sustain attentiveness to soils as active agents. [40] In this sense, soil care advances a more relational and responsible urbanism, one that recognizes soils as foundational to ecological and societal futures.

[34] See Viganò P., Guenat C., *op. cit.*; Kabisch N., Korn H., Stadler J., Bonn A. *op. cit.*
[35] United Nations Environment Programme (UNEP), *op. cit.*; Intergovernmental Panel on Climate Change (IPCC), *op. cit.*
[36] See Mantziaras P., Viganò P., op. cit.
[37] See Schils R., Dekker C., Oenema J., Hilhorst G., Wagenaar, J.P., Verloop K., *op. cit.*
[38] See Secchi B., *op. cit.*; Cohen-Shacham E., Janzen C., Maginnis S., Walters G., *op. cit.*
[39] See Hooimeijer F.L., Tummers-Mueller L.C., *op. cit.*
[40] See Luo S., Naghibi M., Patuano A., van Leeuwen E., *op. cit.*

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