*Figure 1. Aerial view of agricultural fields in Lubbock County, Texas, showing the patchwork of industrial farming shaped by grid and pivot irrigation. This landscape demonstrates the region's dependence on the Ogallala Aquifer, highlighting the urgent need for sustainable, water-efficient practices in a semi-arid environment. Image by Google Earth*

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# [DE]COMPOSITION: GROWING GROUND

By Skylar Perez

## ABSTRACT

Human urbanism is contingent on Microbial Urbanism, just as microbial life is shaped by human activity. Soil is not just the surface beneath us, it is a living, metabolizing matrix that holds memory, biodiversity, and the potential for regenerative futures. Soil is reoriented as a vital actor across architecture, agriculture, and ecological design, particularly in semi-arid regions like Lubbock County, Texas, where unsustainable farming practices and Ogallala Aquifer depletion pose existential threats. Through the lens of Microbial Urbanism, soil is understood as both infrastructure and collaborator, shaped by microbial networks, hydrological systems, and human intervention.

By centering soil's biological complexity, temporal depth, and material intelligence, the paper outlines a paradigm shift: one that designs not around the land but with it. Architecture and agriculture become reciprocal processes, and technologies of care rooted in the rhythms and strata of the living ground.

**Keywords:** *soil care, microbial urbanism, multispecies collaboration, pixel farming, critical zone*

# INTRO

Beneath the Earth's surface exists an often overlooked but vital system sustaining all terrestrial life: soil. Beyond its traditional role as a substrate for agriculture or architectural construction, soil is an active, dynamic ecosystem shaped continuously by microbial communities, including bacteria and fungi, which drive processes like decomposition, nutrient cycling, and growth (Barot et al., 2007). These microbial processes profoundly impact not only agricultural productivity and ecological health but also influence architectural potentials and urban planning, especially in environmentally vulnerable regions such as the Llano Estacado. Given increasing environmental pressures like soil degradation and water scarcity, reorienting how we understand and interact with soil is essential.

This research investigates the Critical Zone of Lubbock County, Texas—a semi-arid region where intensive industrial agriculture and dependence on the rapidly diminishing Ogallala Aquifer have severely compromised the local ecosystem (Rhodes et al., 2023). Practices prevalent in this region, such as monoculture cropping, heavy chemical inputs, and excessive groundwater pumping, accelerate soil degradation, water scarcity, and the vulnerability of local agricultural and urban communities (Allen et al., 2008).

Addressing these critical pressures requires a fundamental rethinking of how agricultural systems and urban developments interact with the region's natural resources. By integrating principles from architecture, microbiology, agriculture, and data-driven technology, design strategies can be curated to prioritize processes of soil care, improving soil health by conserving water, and promoting biodiversity.

Interdisciplinary approaches offer practical pathways for communities in arid and semi-arid regions, ultimately supporting symbiosis between human and non-human life and ensuring ecological and urban resilience into the future.

Microbial communities operate through decomposition, nutrient exchange, and symbiotic relationships with plants, influencing soil fertility, water retention, and overall ecosystem resilience (Guseva et al., 2022). By considering soil through this lens, design and urban planning can incorporate ecological dynamics directly into architectural and agricultural interventions.

By embedding soil microbiology directly into urban and agricultural design, Microbial Urbanism moves beyond metaphor, proposing tangible design methodologies that align human-built environments with microbial ecological processes. This integration supports regenerative outcomes, enhancing resilience, biodiversity, and sustainability.


Examining soil's biological processes across multiple scales, from microbial interactions to landscape dynamics, allows for a deeper understanding of how agricultural practices, architectural design, and ecological resilience can influence each other. The health and sustainability of the Llano Estacado increasingly depends on recognizing soil as a living partner and stakeholder. By engaging with concepts such as Microbial Urbanism, this paper proposes actionable strategies that integrate ecological principles into the built environment and land-use practices. The following sections elaborate on how these methodologies offer tangible solutions to critical challenges including water scarcity, soil degradation, and climate change, ultimately supporting a regenerative future grounded in symbiotic relationships with soil.

## THE CRITICAL ZONE: LUBBOCK COUNTY, TEXAS

The Critical Zone, defined as the thin layer of Earth where rock, soil, water, air, and living organisms interact, is fundamental to sustaining life on our planet (Lee et al., 2023). Lubbock County, Texas faces intense pressures from industrial agricultural practices and rapid depletion of the Ogallala Aquifer, its primary water source The Ogallala Aquifer has experienced significant declines, with water levels dropping by an average of 4.8 meters (approximately 15.7 feet) since intensive pumping began in the 1930s, threatening agricultural viability across the region (Allen et al., 2008). The Llano Estacado, the plateau defining this area, is dominated by alkaline sandy loams and silty clays—soils historically capable of supporting robust agriculture. However, these soils are increasingly degraded due to intensive monocropping, over-irrigation, and heavy chemical usage, which have accelerated soil erosion rates by up to 23% compared to more sustainable farming practices (Yang et al., 2024). The combination of these practices disrupts soil ecology, diminishes microbial diversity, and jeopardizes long-term soil fertility, highlighting the urgent need for alternative strategies.

*Figure 2. Series of satellite images showing the scale of the Ogallala Aquifer, the Llano Estacado plateau, Lubbock County, agricultural land, and a specific farm. These images contextualize the regional focus, emphasizing the spatial dependability of water resources, soil health, and agricultural practices across scales in a semi-arid environment. Image by Skylar Perez*

The depletion of the Ogallala Aquifer is especially critical, as it is the central water source sustaining agricultural and urban communities across the Llano Estacado (Rhodes et al., 2023). Since the onset of intensive agriculture, excessive groundwater extraction has caused a regional water table decline averaging about 0.3 meters per year (Allen et al., 2008). At current usage rates, this aquifer, which supports nearly 30% of the irrigated agriculture in the United States, could become nonviable for large-scale irrigation within the next few decades, dramatically altering farming and community life in Lubbock County (Yang et al., 2024). As water scarcity intensifies, transitioning towards sustainable agricultural practices focused on water conservation and soil regeneration is increasingly imperative.

Central to this transition is recognizing soil as both a substrate for plant growth and a dynamic participant in ecosystem health. Intensive farming practices prevalent across the Llano Estacado, including the application of heavy chemical fertilizers, persistent pesticide use, and inefficient irrigation have degraded the soil. For example, long term applications of nitrogen-based fertilizers have been shown to reduce microbial biodiversity by up to 15%, weakening soil structure and limiting its ability to retain moisture and nutrients (Yang et al., 2024). Restoring soil health through practices that support microbial communities will be key to re-establishing the ecological integrity and agricultural productivity of the Critical Zone.

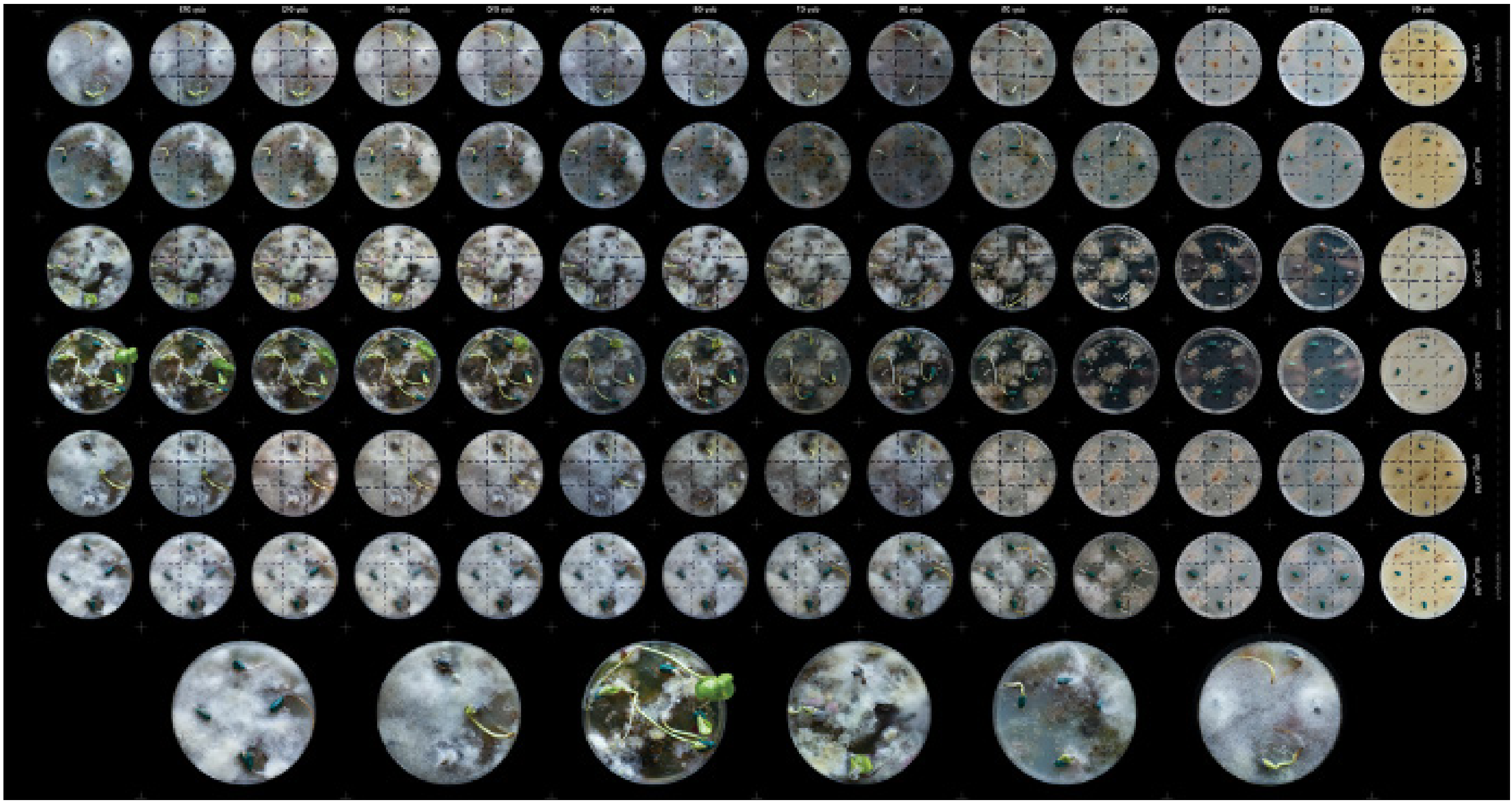
To address the ecological challenges within the Critical Zone, alternative land management strategies must realign human activity with soil's natural processes. Precision agriculture, which utilizes real-time environmental monitoring via sensors and remote-sensing technology, enables farmers to apply water, nutrients, and pest management resources exactly where and when needed, significantly reducing waste and improving resource efficiency (Balafoutis et al., 2017). Pixel farming complements these technological interventions by promoting diversified cropping systems tailored to local soil conditions, enhancing microbial biodiversity and soil resilience (Fahrig et al., 2015). Incorporating microbes through bioremediation strategies and increasing green zones in architectural planning and construction materials, such as soil-based

3D-printed structures, offers innovative pathways toward built environments that actively support soil health, rather than producing toxic materials. These integrated approaches offer sustainable interactions between agriculture, architecture, and ecology, emphasizing practical methods for remediating and regenerating soil, air, and water, while improving crop productivity, ecological stability, and human health.

# MICROBIAL URBANISM

Soil is often perceived simply as a resource for agriculture, construction, or extraction, yet beneath its surface exists a dynamic network of microbial communities actively shaping ecological processes (Guseva et al., 2022). Microbial Urbanism introduces a design methodology that recognizes these underground microbial networks that are composed of bacteria, fungi, and other microorganisms as living infrastructures capable of guiding land use and architectural decisions. By conceptualizing soil as a responsive urban ecosystem, this approach translates microbial processes, such as nutrient cycling, decomposition, and symbiotic plant relationships into actionable design principles. It also provides a program for architecture to respond to and design the spaces that support these processes. In practice, Microbial Urbanism integrates biological insights into the built environment, influencing site planning, soil remediation strategies, material choices, and the creation of habitats that promote microbial and ecological resilience.

*Figure 3. Field site in Lubbock County, Texas, showing soil samples analyzed through petri dish cultures to reveal organization of microbial diversity, and plant-microbe interactions. Image by Skylar Perez*



A critical dimension of Microbial Urbanism is understanding how soil microbes and plants coexist spatially, shaping their shared environment through communication and resource exchange. In a controlled experiment (Figure 4), petri dishes containing three types of nutrient-rich agar—fungi-nutrient, bacteria-nutrient, and a balanced nutrient composition were combined with soil samples and microbes from Lubbock, Texas, and two local varieties of cotton seeds. Observations over thirteen days revealed distinct spatial patterns in microbial and plant interactions, demonstrating that microbial distribution significantly influenced plant growth and overall ecosystem vitality. These insights into microbial spatial organization provide guidance for designing landscapes and architectural interventions that foster symbiotic relationships between microorganisms and vegetation, thereby supporting soil health, ecological resilience, and optimized plant productivity.

The spatial dynamics observed in microbial-plant interactions not only provide models for design but also deepen our conceptual understanding of soil biodiversity as a foundational ecological principle. Biodiverse soil systems demonstrate greater resilience against environmental stresses, including drought and disease, due to their enhanced capacity for adaptation and resource distribution. This diversity within the soil acts similarly to biodiversity in larger ecosystems, where varied species support more robust, flexible, and sustainable environments.

*Figure 4. Petri Plot Experiment showing soil and plant interaction experiment over 13 days. Image by Skylar Perez*

Translating this microbial biodiversity into practical agricultural strategies involves fostering complex, multispecies soil communities that can naturally regulate pests, recycle nutrients, and enhance crop yields without heavy reliance on chemical inputs or excessive water usage. Such strategies significantly contribute to the sustainability and resilience of agricultural lands, where conventional farming methods exacerbate environmental degradation. From the scale of a single agricultural plot to an interconnected network of diverse farms, biodiverse soils serve as ecological building blocks that support regional food security, water conservation, and climate adaptation.

When scaled further to urban and regional planning, the principles of Microbial Urbanism propose integrating agricultural practices and urban environments through shared ecological strategies. Urban agriculture, community gardens, green roofs, and soil-integrated public spaces become opportunities to introduce biodiverse microbial ecosystems into cities and human culture. This microbial-informed planning fosters urban resilience by managing stormwater, reducing urban heat islands, and creating healthier, more productive green spaces. In turn, urban areas benefit from strengthened ecological connectivity to peri-urban and rural agricultural zones, facilitating nutrient flows, biodiversity corridors, and improved food security.

Microbial Urbanism articulates a multi-scalar vision in which the microscopic biodiversity of soil underpins the ecological health and resilience of agricultural and urban systems alike. Embracing this microbial perspective shifts the traditional paradigm, positioning soil biodiversity not merely as a supportive element but as a central determinant in designing and sustaining resilient agricultural landscapes and thriving urban ecosystems.

## LAND-USE AND PRECISION AGRICULTURE

As agricultural systems evolve, practices like pixel farming and precision agriculture offer innovative ways to engage with the land, challenging traditional farming's intensive, large-scale monocropping. These approaches leverage technology such as remote sensing, soil electrical conductivity mapping, and yield monitors to identify spatial variability within agricultural fields, enabling targeted interventions (Guo, 2018). By managing small segments or "pixels" of land based on their unique characteristics, farmers can significantly reduce resource consumption and environmental degradation. Precision agriculture provides essential methods to optimize water use, enhance soil health, and foster biodiversity at both regional and global scales (Guo, 2018).

Pixel farming involves cultivating diverse crops within smaller, interwoven plots that reflect the natural heterogeneity of the soil. Rather than applying a uniform treatment to a field, this method tailors plant selection and care to the ecological conditions of each plot. By encouraging crop diversity adapted to varying soil profiles, pixel farming fosters more resilient plant-microbe interactions. This biodiversity supports soil health, reduces dependence on chemical fertilizers and pesticides, and naturally suppresses pests through ecological balance. The result is a dynamic agricultural mosaic, where each "pixel" becomes a regenerative micro-ecosystem that contributes to the broader health of the land (Fahrig et al., 2015).

Precision agriculture builds on this ecological logic by integrating remote sensing, yield data, and soil health metrics to inform decision-making at a hyper-local scale.

Technologies such as GPS-guided equipment, variable-rate irrigation, and soil moisture sensors allow farmers to apply inputs, water, nutrients, and amendments, only where and when they are needed (Guo, 2018). Spatial and temporal precision in managing cotton and other crops has been shown to significantly reduce water usage while maintaining or improving yields (Guo, 2018). By prioritizing soil vitality and optimizing input use, precision agriculture realigns land management practices with environmental realities and opens pathways for climate-adaptive farming at regional scales.

As these practices scale, their influence extends beyond the field, shaping regional land-use patterns and contributing to planetary climate strategies. On the Llano Estacado, integrating precision agriculture with real-time environmental monitoring could reduce strain on the Ogallala Aquifer and stabilize degraded soils, buffering against desertification and economic decline. These systems build networks of care that reach into urban supply chains, water management infrastructures, and regional policy frameworks. The agricultural field becomes a data-rich, adaptive landscape that mirrors urban systems in complexity and interconnectivity. Globally, these shifts position agriculture not as an isolated sector at the hinterlands of our cities, but as a keystone in climate action, capable of sequestering carbon, reducing emissions, and responding to changing ecological conditions with intelligence and flexibility.

Healthy soils function not only as ecosystems but as powerful carbon sinks, stabilizing organic matter and storing atmospheric carbon. Practices like pixel farming and precision agriculture enhance this function by minimizing soil disturbances like tilling and encouraging microbial diversity, which together enrich the soil's structure, fertility, and water retention (Averill et al., 2022).

In regions like Lubbock County, where aquifer depletion and land degradation threaten ecological stability, these approaches invite a redefinition of farming itself. By treating soil as a collaborator and the farm as a responsive, living system, we move toward design strategies that link care, reciprocity, and long-term survival.

## FUTURE FARMS: ECOLOGICAL SHIFTS

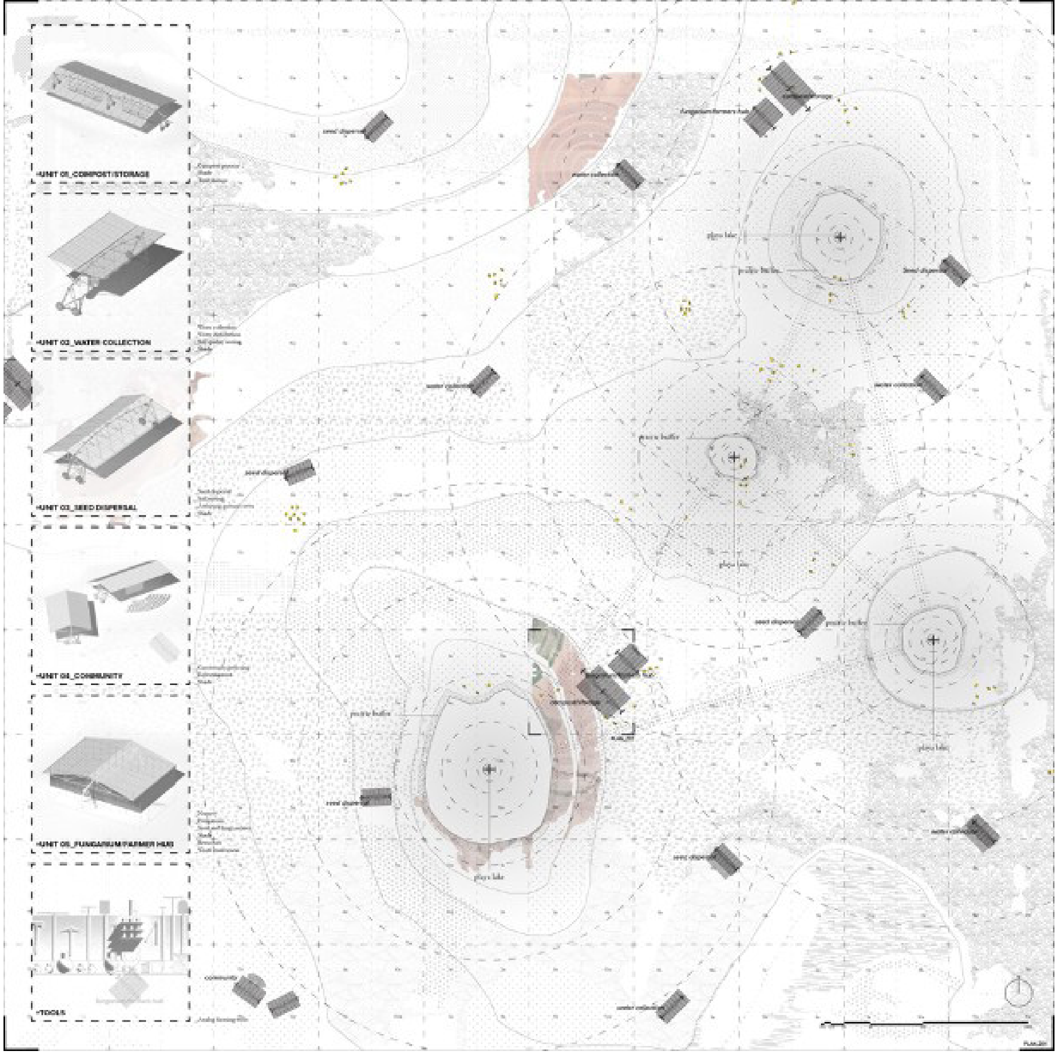
The pressures on modern agriculture demand a radical rethinking of how we interact with the land. Conventional practices, often defined by monocropping, chemical inputs, and mechanized infrastructure, extract resources with little regard for long-term ecological health (Pacini et al., 2003). These approaches lead to compacted soils, diminished biodiversity, and the accelerated depletion of water sources. In semi-arid conditions, these effects are intensified by climate change, revealing the urgent need to establish new systems of cultivation and care.

This speculative model of a future farm proposes an integrated and ecologically responsive approach to land use that prioritizes regeneration over extraction. Each parcel of land can be measured as an active contributor to ecosystem health, capable of adapting, revitalizing, and co-evolving with human activity. Strategies including pixel farming, precision agriculture, and adaptive reuse support a shift toward biodiverse, decentralized landscapes. In addition to food production, the future farm plays a key role in restoring degraded soils through bioremediation strategies. Techniques such as biopiling, already in use for remediating soils in arid regions (Smith et al., 2015), can be adapted to local conditions to replenish microbial communities and detoxify the land.

Land-use planning and design becomes instrumental in this transformation, as planning includes not only the lives of the human, but also the unseen lives that operate within soil.

Rather than constructing human boundaries with conventional fencing to define property, boundary conditions can evolve into living infrastructures. Windbreaks composed of native phreatophytes like honey mesquite (Prosopis glandulosa) serve multiple roles—reducing erosion, stabilizing soil, and accessing deeper groundwater reserves (Ansley & Hart, 2012), all while creating underground habitats that support microbial and plant biodiversity.

This reorientation of soil and land reimagine existing infrastructures in ways that enhance adaptability and ecological sensitivity. Traditional pivot irrigation systems, once responsible for excessive irrigation, are reimagined as light-


UNIT 01_COMPOST/STORAGE
UNIT 02_WATER COLLECTION
UNIT 03_SEED DISPERSAL
UNIT 04_COMMUNITY
UNIT 05_FUNGARIUM/FARMER HUB
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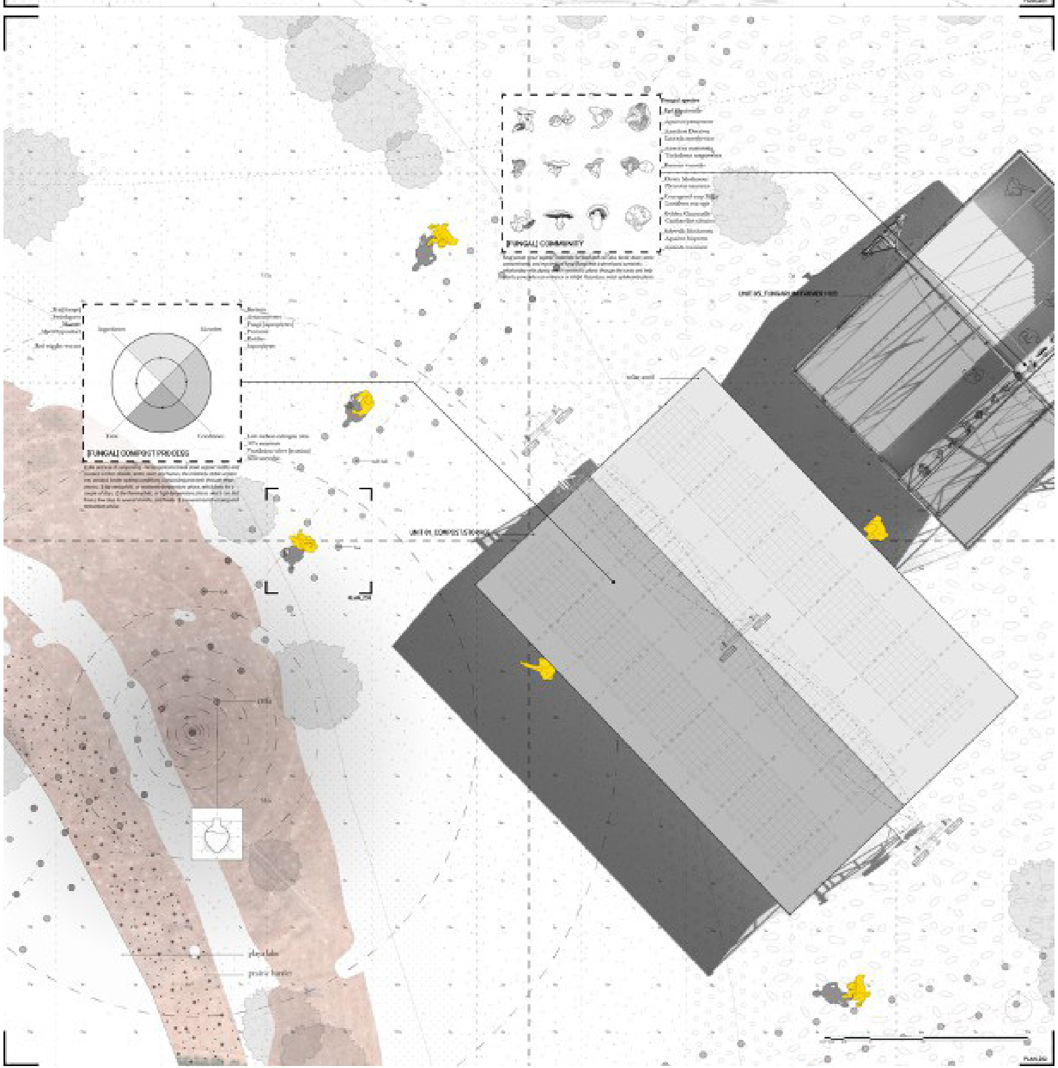
water collection
playa lake
prairie buffer
community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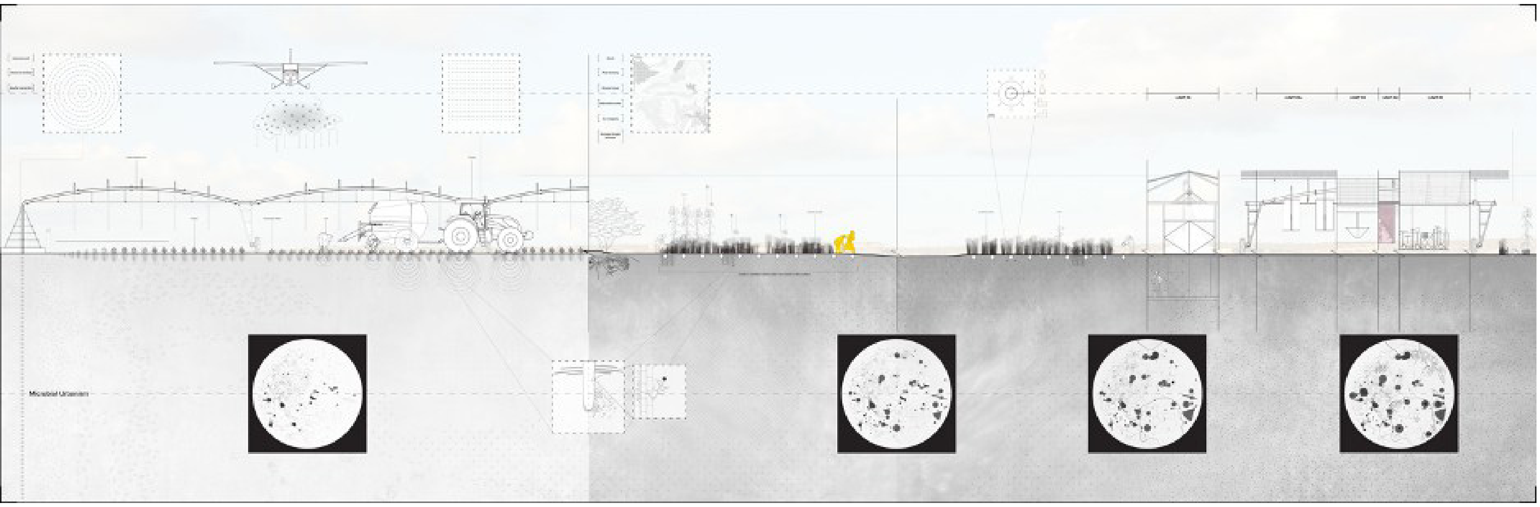

weight, sensor equipped frameworks that travel across the field. These re-adapted systems are capable of monitoring soil moisture, nutrient availability, and crop health in real time, creating a dynamic and site-specific view of the landscape. Instead of indiscriminately applying water, fertilizers, or pest control, this localized care reduces input waste, minimizes environmental degradation, and supports healthier, more resilient soils.

These adaptive systems allow the future farm to sense the environment on a detailed, responsive level, revealing the often-invisible dynamics of soil health, microbial activity, and plant vitality. By adopting these new lenses of observation, land stewardship becomes more proactive, attuned to subtle environmental changes, and capable of mitigating the effects of climate change. Reusing and adapting existing infrastructure becomes part of a regenerative agricultural practice, transforming the farm into a responsive, evolving system shaped by the land's specific needs.

This vision of farming moves beyond the production of food and crops. It frames the farm as a living, interconnected landscape that sustains both human and non-human life. Waste is recirculated into useful forms, and resources are sourced locally to meet the needs of the farm and its surrounding

*Figure 5 (Top Left). Plan for an adaptive, ecologically responsive farm layout, showing integrated units for compost storage, water collection and dispersal, seed dispersal, community gathering, and a fungarium farmer hub. Image by Skylar Perez*

*Figure 6 (Bottom Left). Detailed plan of the fungarium and compost storage unit within the speculative future farm model. This layout illustrates the integration of fungal communities into composting processes, enhancing soil health and nutrient cycling. Image by Skylar Perez*

*Figure 7 (Top Right). Sectional view of the speculative future farm model, illustrating the integration of microbial urbanism into farming practices. Image by Skylar Perez* communities. By reducing dependence on distant supply chains, these locally sourced materials create a closed-loop system that supports both ecological and cultural resilience.

The future farm model introduces carbon credits as an incentive for farmers to adopt sustainable practices. By promoting microbial biodiversity, enhancing soil organic carbon, and increasing above- and below-ground biomass, such farms can participate in carbon credit systems, turning land stewardship into a viable form of climate currency (Meena et al., 2024). Similar to agroforestry models implemented on degraded lands in India, the Llano Estacado region holds potential for similar socio-ecological transformations. These incentives can reshape rural livelihoods, incentivizing environmental gains with economic security.

## CONTINGENT URBANISMS: MAKING TIME FOR SOIL

Human urbanism is contingent on Microbial Urbanism. The future of cities, agriculture, and ecological life depends on humans' capacity to care. Soil is not inert, it is time accumulated. It is memory, metabolism, and matter in constant transformation. It is the original architecture, and the foundation of which all architecture is embedded.

This shift extends beyond materials. It is spatial, temporal, and ethical. It asks us to recalibrate our timescales to match those of decomposition, mycelial growth, root exchange, and carbon formation. The rhythms of the Critical Zone, of water infiltration, microbial reproduction, and nutrient cycling must become design criteria. In this view, time is no longer measured by development cycles or harvest seasons alone, but by the biology of time.

If soil holds time, then technology can help us see it. Data systems, sensors, and remote sensing can be leveraged not to dominate the land, but to observe and archive its thresholds. These tools become an archive of human interaction, mapping inputs, degradation, restoration, and recovery to help make the unseen visible.

For farming communities, this offers new forms of stewardship, including access to carbon markets, land regeneration initiatives, and localized material economies. For cities, it suggests that resilience begins in the soil, not in concrete. Urban infrastructure must reconnect with rural ecologies, blurring the line between what is "urban" and "agricultural." Ecotourism, education, and participatory land management programs create new relationships between citizens and soil, building human consciousness around the living ground.

## CONCLUSION

Soil is the container of life, a living substrate, a repository of memory, and a vital collaborator in mitigating the effects of climate change. Reorienting our design practices around soil means recognizing its complexity as a system shaped by microbial networks, human interventions, and layered histories of care and extraction.

In the Llano Estacado, where aridity, water depletion, and monocultural exhaustion threaten long-term viability, the soil reveals both crisis and potential. When viewed through the lens of Microbial Urbanism, new strategies begin to emerge. These strategies integrate biological intelligence, localized materials, and multispecies cohabitation into how we build, grow, and live. From site-specific experiments to speculative future farms, this work illustrates that responsive design is not only about form or function, but about cultivating symbiotic relationships rooted in the land.

*Figure 8. A 3D-printed olla crafted from locally sourced and "processed" soil, and clay. The traditional, unglazed water vessel is embedded in soil and slowly wicks water to maintain optimal moisture levels for surrounding plants. Image by Skylar Perez*

The future of architecture, agriculture, and planetary health depends on this shift. We must move beyond the abstraction of nature as a passive backdrop and learn to design with the unseen.

Making time for soil care calls for a shift in values, where observation, adaptation, and design evolve in tandem with biological processes. It is a commitment to understanding the land, and learning from microbial processes to create built and agricultural systems that operate at the pace of biology. Soil is positioned as our foundation and our future, it becomes a guide for reimagining how we inhabit Earth.

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