Check for updates

Latest updates: https://dl.acm.org/doi/10.1145/3715336.3735404

RESEARCH-ARTICLE

Diffractive Interfaces: Facilitating Agential Cuts in Forest Data Across More-than-human Scales

ELISA GIACCARDI, Politecnico di Milano, Milan, MI, Italy

SEOWOO NAM

IOHANNA NICENBOIM, Delft University of Technology, Delft, Zuid-Holland, Netherlands

Open Access Support provided by:

Politecnico di Milano

Delft University of Technology

PDF Download
3715336.3735404.pdf
29 March 2026
Total Citations: 1
Total Downloads: 2158

Published: 04 July 2025

Citation in BibTeX format

DIS '25: Designing Interactive Systems Conference
July 5 - 9, 2025
Madeira, Portugal

Conference Sponsors:
SIGCHI

DIS '25: Proceedings of the 2025 ACM Designing Interactive Systems Conference (July 2025)
https://doi.org/10.1145/3715336.3735404
ISBN: 9798400714856

Diffractive Interfaces

Facilitating Agential Cuts in Forest Data Across More-than-human Scales

Elisa Giaccardi
Politecnico di Milano
Milan, Italy
elisa.giaccardi@polimi.it

Seowoo Nam
Clever Franke
Utrecht, The Netherlands
97seowoo@gmail.com

Iohanna Nicenboim
Delft University of Technology
Delft, The Netherlands
i.nicenboim@tudelft.nl

ABSTRACT

As cities worldwide adopt data-driven approaches to optimize urban forests, computational tools like agent-based models (ABMs) are increasingly popular to simulate forest growth and inform planting decisions. However, ABMs often focus on individual metrics, neglecting forests as interdependent ecosystems. Rooted in anthropocentric ideals, these models risk reducing forests to infrastructures for human benefit, undermining their long-term resilience. This pictorial challenges these limitations by exploring how interface design can transcend reductive, agent-centric representations to foster relational understandings of forest ecosystems as more-than-human bodies. Drawing on feminist theorist Karen Barad's concepts of "diffraction" and "agential cuts," we craft a repertoire of diffractive interfaces that engage with forest simulation data, revealing how more-than-human bodies can be encountered across diverse temporal, spatial, and agential scales. Through this design exploration, we operationalize more-than-human perspectives in data practices, deepening our understanding of the performative dimensions of interfaces and advancing nuanced, practical approaches to more-than-human design.

Authors Keywords

Urban forest, forest ecosystem, data, interface, agential cut, diffraction, more-than-human bodies, more-than-human design

CSS Concepts

• Human-centered computing~Interaction design

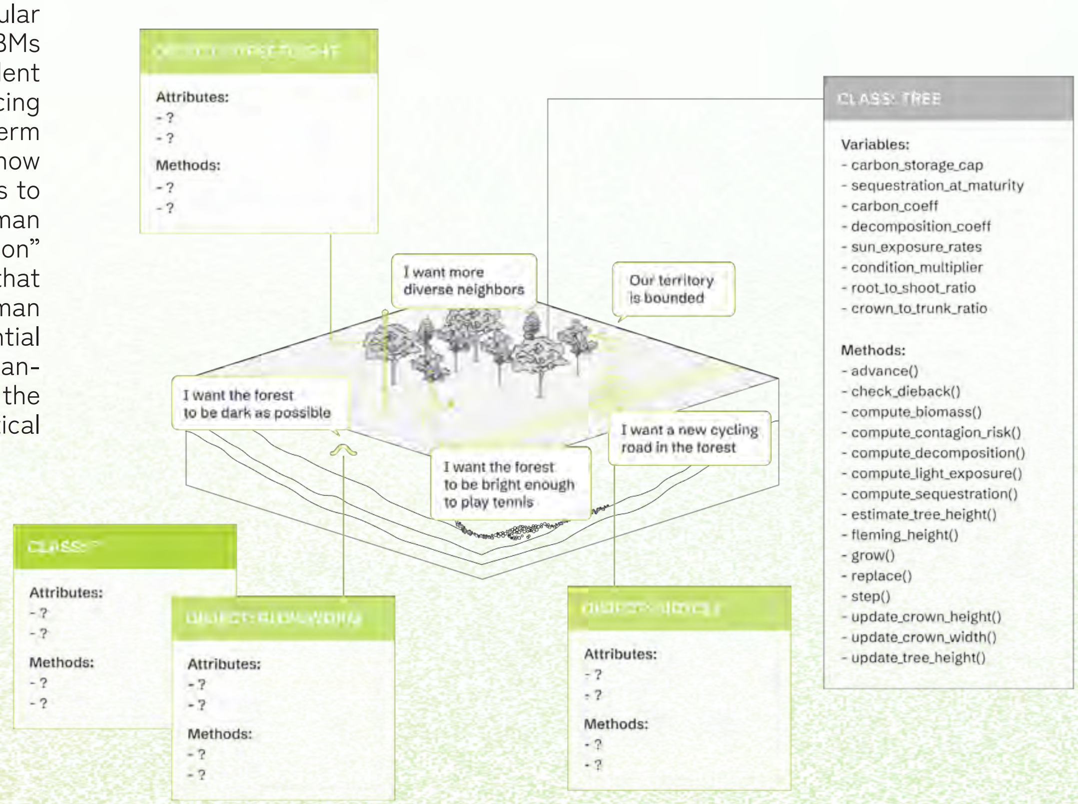
CC-BY

This work is licensed under Creative Commons Attribution International 4.0.

DIS '25, July 5–9, 2025, Funchal, Portugal

© 2025 Copyright is held by the owner/author(s).

ACM ISBN 979-8-4007-1485-6/2025/07.
https://doi.org/10.1145/3715336.3735404



More-than-human model of a forest as a shared ecology where multiple entities, not just trees, are represented as agents with competing priorities.

INTRODUCTION

The urgency of climate change has led cities to increasingly treat nature as programmable urban infrastructure to address environmental challenges [5]. Urban forests are now seen as “smart” assets, managed via data-driven systems to optimize ecosystem services such as carbon sequestration, flood control, and temperature regulation [24]. These approaches aim to enhance urban ecologies’ efficiency, aligning with sustainability visions tied to technological innovation and economic growth [31].

Within this framework, agent-based models (ABMs) have become key tools for managing urban forests, simulating ecological interactions through computational agents with defined behaviors. ABMs help predict outcomes of management strategies, guiding decisions about tree planting and care. However, Gabrys [5] warns that these models often perpetuate extractive economies and social inequalities by simplifying forest ecosystems into programmable entities, embedding anthropocentric biases, and marginalizing broader ecological dynamics.

Westerlaken et al. [33] further highlight the exclusion of nonhuman participants in decision- making, noting that forests are shaped by multispecies interactions. This reductionist approach risks fragmenting ecological systems, undermining urban forests’ resilience and their ability to sustain balanced urban environments in the long term.

This critique highlights that modeling and representing forests through data are not neutral technical choices but material-discursive practices that shape how we understand and interact with forests. As Karen Barad asserts, “practices of knowing are specific material arrangements that participate in reconfiguring the world” [1, p. 91].

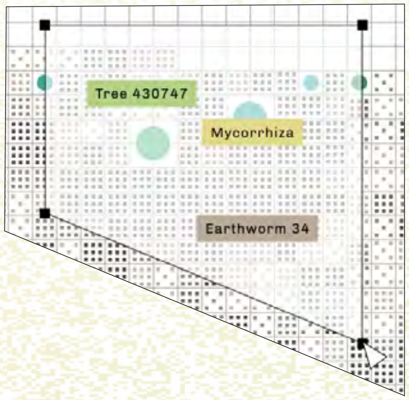
In response, this pictorial introduces a feminist, more-than-human design approach [7, 25, 27 , 29] to engaging forest simulation data.

Instead of reducing computational agents to static entities, we explore digital interfaces that emphasize forests as dynamic, relational more-than-human bodies.

Central to our design exploration is the concept of diffractive interfaces, inspired by Barad’s notions of “agential cuts” and “diffraction” [1], which focus on how measurement practices shape realities and encourage attentiveness to differences and their material impacts.

The pictorial begins with illustrating how computational representations shape our understanding of forest ecosystems through specific temporal, spatial, and agential parameters. Building on this, it visually explores the notion of the “more-than-human body” [14] as an alternative to engage diffractively with computational agents.

This exploration culminates in the design of a series of interface concepts that enable interaction with the same forest simulation data across diverse temporal, spatial, and agential dimensions. By framing forests as more-than-human bodies, these diffractive interfaces foster relational, multispecies engagement, promoting ecologically attuned ways of understanding and interacting with forest data.



Grouping entities into clusters to explore them as relational systems, rather than as individual agents.

RELATED WORK

HCI increasingly focuses on multispecies care, cohabitation, and kinship, inspired by posthuman, more-than-human, and ecofeminist onto-epistemologies, with a particular focus on the work of Donna Haraway [11]. While this pictorial aligns with these efforts in ethos, its primary contribution lies in bridging research on the role of data in engaging ecosystems from a more- than-human perspective [9, 15] with studies on the material-discursive and performative dimensions of data practices [17, 22, 26]. In what follows, we briefly unpack these connections and the knowledge gaps we aim to address.

More-than-human approaches to ecosystem data

Originating from the imperatives to move beyond anthropocentric data practices [9, 15], HCI researchers have begun to explore more- than-human approaches to understanding and interacting with ecosystems through data. These works range from strategies for decentering [19] to enriching urban datasets based on relational ontologies [4], participatory methodologies of “walking-with” forests to collect embodied and situated forest stories [3], co-design fictions to generate relational thought about nonhuman stakeholders [23], and the design of an open-data research platform fostering pluralistic and participatory understanding of smart forests [32].

While these works open up critical questions about human-environment-data relationships, many interventions remain speculative, often focusing on collecting new types of datasets or proposing entirely new infrastructures and systems. This leaves a gap in understanding how more-than-human perspectives could be operationalized within current data practices.

Design research also increasingly highlights the entangled factors in data production – people, context, knowledge, sensors, analysis, and visualization [10, 28]. While these studies reveal the infrastructures enabling data, little attention has been given to how interface design can expose and intervene in these more-than-human entanglements.

Diffractive data practices in HCI

Within the HCI research community addressing the material-discursive and performative dimensions of data practices, Sanches et al. [26] have explored the concept of "lived data" through diffractive design processes, highlighting the felt and prospective dimensions of data as it entangles with everyday lives. Drawing on Barad [1], they employ "diffraction" as a mode of inquiry that attends to differences, interferences, and entanglements within the ongoing phenomenon of data production. Building on this foundation, Morrison and McPherson [17] extend the use of diffraction in their development of a method called "diffractive dialogue." This method, inspired by Barad's notion of "diffractive reading," involves each author responding to a series of discussion prompts through the lens of their disciplinary backgrounds. By bringing these differing perspectives into conversation, they demonstrate how diffraction can serve as a collaborative, interdisciplinary tool for unpacking the entanglements and implications of data practices (see also, [22] and [30]).

While these prior works illuminate the potential of diffractive engagements during the design or conceptualization process, they largely center on the experiences and practices of designers and researchers themselves. This leaves an important gap in understanding how interaction design can enable others - such as stakeholders, end-users, or communities - to engage diffractively with data in their everyday sensemaking practices. Our work aims to address this gap and open new pathways for fostering relational and more-than-human approaches to data engagement, empowering diverse actors to actively participate in the reconfiguration of human-environment-data relationships.

BACKGROUND: THE VLIEGENBOS URBAN FOREST

Our design journey began in Vliegenbos, the oldest urban forest in the municipality of Amsterdam, with an inquiry into current data sensemaking practices in urban forest management. This inquiry combined the analysis of an open source agent-based model of urban forest and tree dataset from the Amsterdam municipality, coupled with ethnographic fieldwork in Vliegenbos. This combined analysis of computational modeling, municipal data practices, and field observations sensitized us to both the capabilities and constraints of current data sensemaking practices in urban forest management. In particular, the ethnographic fieldwork in the Vliegenbos forest [18] provided a contrasting perspective to computational and administrative representations.

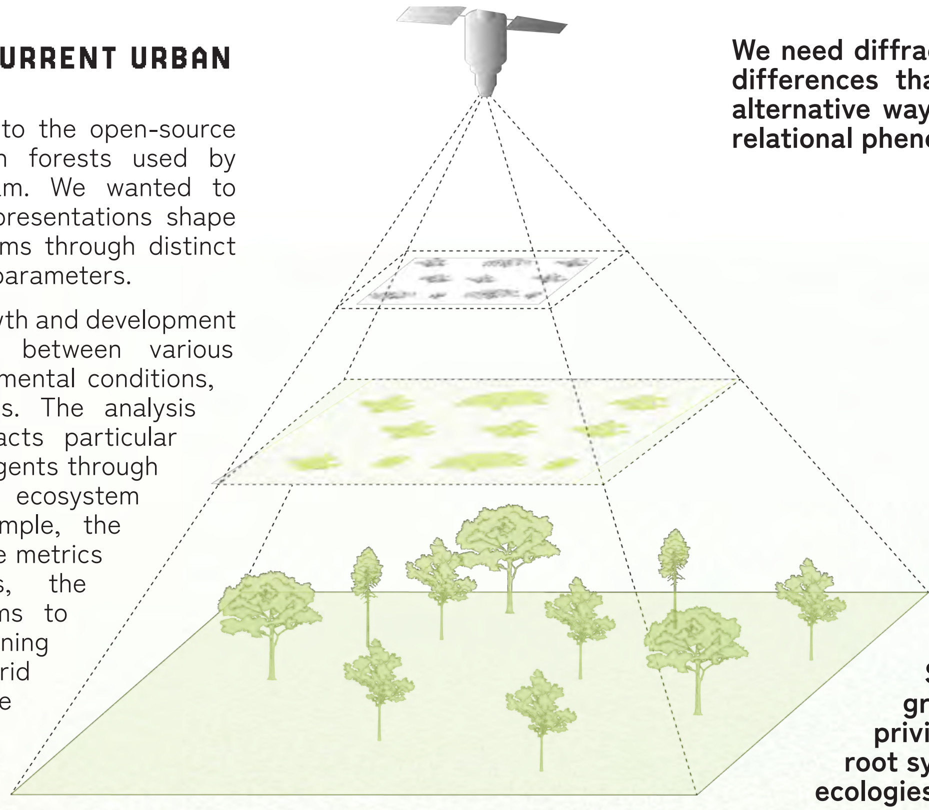
Direct observations revealed temporal rhythms operating at multiple scales simultaneously—from daily cycles of animal activity to seasonal changes in vegetation to long-term forest development patterns.

The fieldwork also highlighted the intricate spatial relationships between trees and other forest inhabitants that extend beyond the grid-based representation, including patterns of undergrowth, wildlife movement, and visitor usage. While these insights were crucial in shaping our understanding, this paper does not focus on these aspects but instead illustrate the design exploration that emerged from this research. For details on these aspects of the work, see [18].

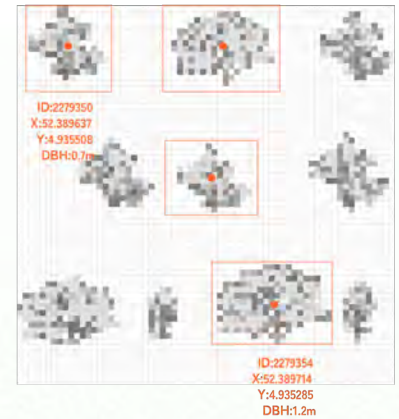
DECONSTRUCTING THE CURRENT URBAN FOREST MODEL

We began with a deep dive into the open-source agent-based model for urban forests used by the municipality of Amsterdam. We wanted to explore how computational representations shape perceptions of forest ecosystems through distinct temporal, spatial, and agential parameters.

The model simulates forest growth and development by representing interactions between various agents including trees, environmental conditions, and management interventions. The analysis revealed how this model enacts particular "agential cuts" [1] by defining agents through measurable attributes and ecosystem service calculations. For example, the privileging of above-ground tree metrics over underground networks, the reduction of temporal rhythms to annual cycles, and the flattening of spatial relationships into grid coordinates all reflect how these models embed specific ways of knowing and relating to forests.



We need diffractive approaches that can attend to the differences that particular "cuts" make and explore alternative ways of understanding forests as dynamic, relational phenomena.



Spaceborn LiDAR data captures above-ground tree structures like canopy height, privileging visible metrics while overlooking root systems, complex temporalities, and spatial ecologies.

Temporal Parameters

The model operates on a yearly cycle, with each step representing one year of forest growth. Temporal markers like frost-free days and leaf-on/off periods are used to calculate ecosystem services, such as carbon sequestration and water retention. This temporal structuring simplifies the complex rhythms of forest life into measurable units optimized for service metrics.

Spatial Parameters

The model represents the forest as a digital grid, assigning trees discrete x and y coordinates and incorporating site characteristics like soil type, size, inter-tree distances, and sun exposure. Spatial parameters inform metrics like shade factor and crown light exposure, enabling quantitative analysis but oversimplifying the complex and three-dimensional interconnectedness of forest spaces.

Agent Representation

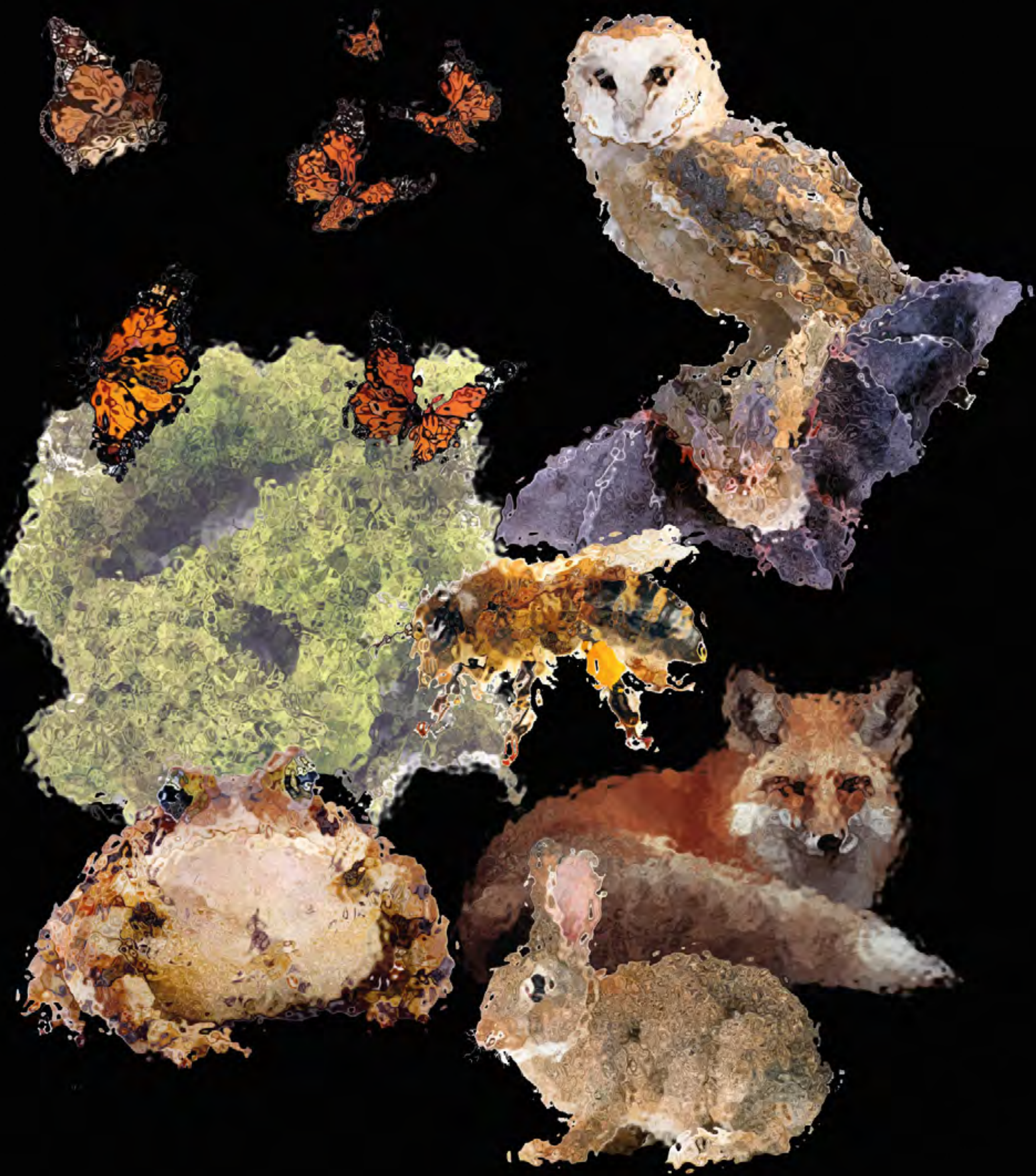
The model defines agents based on assumptions about measurable aspects of forest entities. Trees, as primary agents, are quantified by attributes like diameter at breast height (DBH), species, height, and condition, forming the basis for ecosystem service calculations, including flood control and temperature regulation. Environmental factors, such as sun exposure and soil conditions, are similarly reduced to numerical parameters.

FROM COMPUTATIONAL AGENTS TO MORE-THAN-HUMAN FOREST BODIES

As an alternative, we foregrounded the concept of more-than-human bodies to engage diffractively with computational agents. The notion of more-than-human body, as articulated by Homewood et al. [14], recognizes that bodies are simultaneously subjects and objects: they sense and are sensed, shape and are shaped by their environments. Building on more-than-human bodies as a concept for designing—and drawing from both municipal data on Vliegenbos and our direct observations [18]—

we explored more-than-human bodies within the forest ecosystem and investigated how different bodies (e.g., an earthworm or the tangible manifestations of a spring over migratory birds' behavior) enact different agential cuts on temporal, spatial, and agential scales.

In the following pages, we present examples of how more- than-human bodies challenge the rigid parameters and static representations of agents central to agent-based modeling by embodying dynamic, multispecies entanglements. These examples illustrate how forests can be understood as living, relational assemblages rather than fixed categorical entities and abstracted datasets, emphasizing the shifting, interdependent agencies that emerge through ongoing interactions, or rather "intra-actions" [1], across multiple temporal, spatial, and agential scales.



Temporal Scales

An **earthworm's** more-than-human body connects to temporal scales that far exceed its individual lifespan. As it burrows through the soil, intricate networks of tunnels and passages that can persist for years or even decades are created. These enduring traces become conduits for water, air, and nutrients, shaping the very structure and fertility of the forest floor. The castings left behind by generations of earthworms accumulate over time, gradually altering soil composition and influencing the growth patterns of plants above ground. Through its bodily traces, an earthworm bridges the timescales of individual lives and ecological legacies.

The more-than-human body of a **spring** manifests as a cascade of temporally coordinated events. As rising temperatures and lengthening daylight hours signal the end of winter dormancy, flowers bloom in precise sequences, each species cued to open at just the right moment to attract pollinators. The arrival of migratory birds is synchronized with the peak abundance of insect larvae, ensuring a rich food supply for hungry nestlings. Through the coordinated rhythms of countless bodies, the season of spring emerges as a palpable presence in the forest.

Each more-than-human forest body embodies unique conceptions of time, space, and agency, illustrating how alternative "cuts" can foster richer ecological engagement.

Spatial Scales

A **tree's** more-than-human body extends far beyond its visible form, blurring the boundaries between above and below, self and other. Beneath the soil, intricate root networks stretch outward, intertwining with fungal partners to form vast mycorrhizal associations. These subterranean connections enable the exchange of nutrients and chemical signals between trees, creating an "underground internet" that dissolves notions of individual identity. Above ground, a tree's canopy becomes a microcosm of entangled life - a mosaic of leaves, twigs, and branches that provide shelter, food, and substrate for countless creatures. Through its extensive reach, a tree's body challenges bounded conceptions of spatial identity.

An **insect's** more-than-human body defines space through its multiscalar movements and interactions. On the microscale, an insect navigates a complex topography of surfaces – the ridged bark of a tree trunk, the waxy cuticle of a leaf, the delicate petals of a flower. Each texture and contour becomes a distinctive microworld to be traversed and negotiated. Yet, an insect's spatial reach extends far beyond its immediate surroundings, as its foraging paths and dispersal flights connect distant patches of resources into expansive macronetworks. Through its bodily movements, an insect reveals the multiple spatial scales that constitute forest ecosystems.

Agential Scales

The agency of **Dutch elm disease** emerges through the specific relational configuration of bark beetles and fungi. When certain species of bark beetles carry spores of the fungus Ophiostoma novo-ulmi into the vascular tissues of elm trees, the resulting fungal growth blocks water transport and causes rapid wilting and death. But not all bark beetle-fungus associations result in disease. It is the particular ecological and evolutionary history of these species that has produced such a virulent outcome. This demonstrates how agential capacities - in this case, the capacity to radically transform forest composition - emerge through the contingent relationships between heterogeneous bodies.

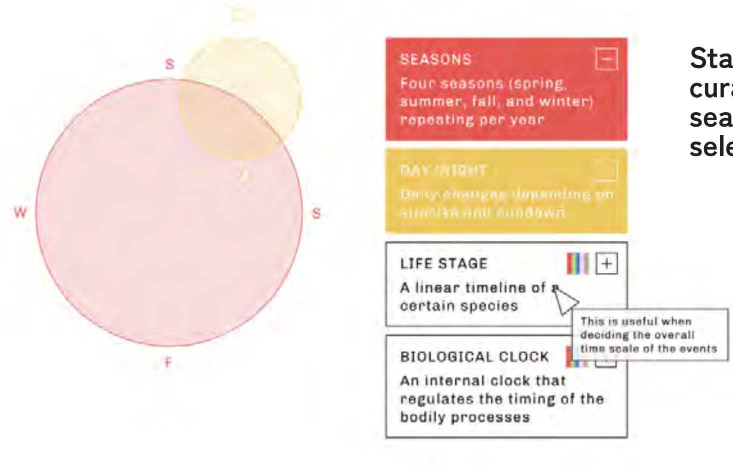
A **soil microbe's** more-than-human body participates in complex networks of nutrient cycling and transformation. As bacteria, fungi, and other microorganisms process dead organic matter, they release essential nutrients back into the soil for uptake by plant roots. These microbial bodies become nodes in an intricate web of chemical exchange, facilitating the flow of energy and materials through the forest ecosystem. The specific composition and interactions of the soil microbiome can have far-reaching effects on plant growth, community structure, and even atmospheric carbon dynamics. Through their networked bodily processes, soil microbes shape the emergent properties of the forest as a whole.

DESIGN CONCEPTS: INTERFACING AS AGENTIAL CUT

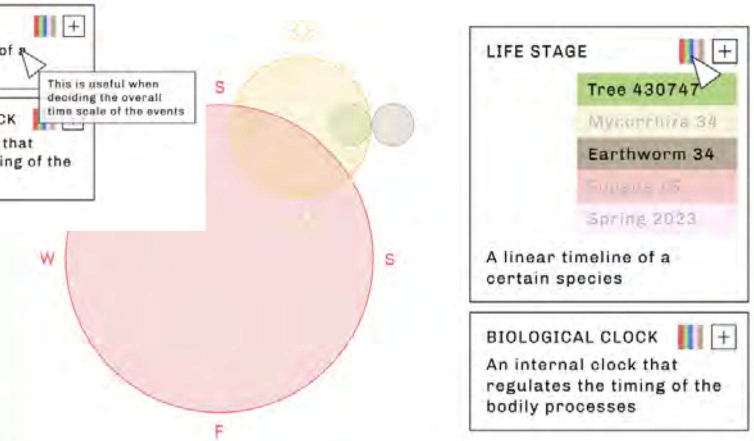
Building on insights from our exploration of more-than-human bodies, we developed a series of interface concepts designed to explore forest simulation data through diverse temporal, spatial, and agential dimensions. These designs do not aim to represent the forest "as it really is" [6]. Instead, they embrace the situated and partial nature of all knowledge production, inviting users to engage with the forest in more open-ended and diffractive ways. Each interface concept enables stakeholders to enact different "cuts" on the data, allowing for varied perspectives on forest phenomena. Timelines, views, and clusters act as specific "agential cuts" [1], foregrounding certain dimensions of the forest while backgrounding others. By making these cuts explicit, the interfaces are meant to facilitate a more nuanced and relational engagement with the forest, encouraging stakeholders to explore multiple, overlapping stories about its futures.

Temporal Interfacing: Lifespans and Timelines

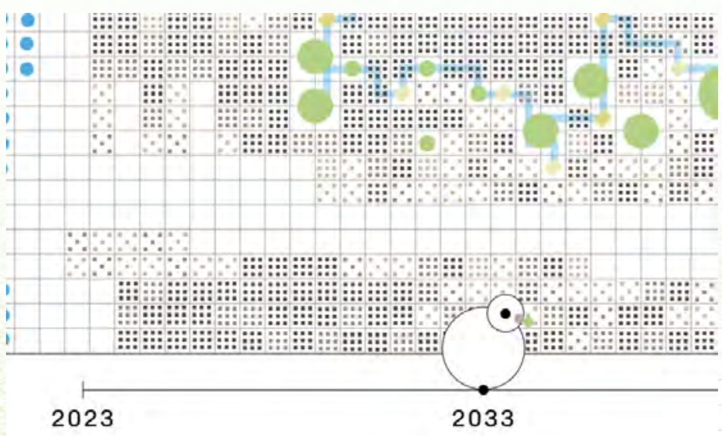
With the temporal interface, we explored how to move beyond the linear yearly cycles of agent-based models to reveal multiple rhythms and temporalities within forest data. Stakeholders can explore forest futures through different temporal lenses - from the daily and seasonal cycles of birds and pollinators to the extended timescales of soil formation through earthworm activity. The interface achieves this through customizable timelines that acknowledge different ways of experiencing time in the forest. Stakeholders can toggle between cyclical rhythms (like seasons and day/night patterns) and linear progressions, or create multispecies timelines that show how different organisms' lifecycles intersect and influence each other. For example, the interface can reveal how the timing of spring emergence coordinates multiple bodies - from flower blooming to pollinator activity to fruit production - showing how forest futures emerge through intricately timed relationships rather than simple yearly increments.



Stakeholders can design a timeline to curate the simulation results. Diverse seasonal or temporal rhythms can be selected and added.



By selecting multiple species, the user can create a timeline consisting of diverse biological clocks or life stages of respective species.

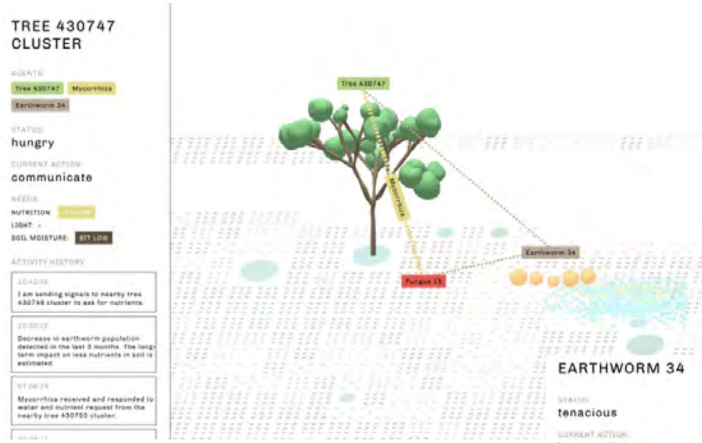


The customized timeline is shown as an icon in the time bar at the bottom of what is referred to as "macro view."

Instead of a numerical representation, time is visualized relative to each species' lifespan. Colored bars on the time axis represent the lifespan of each respective species.

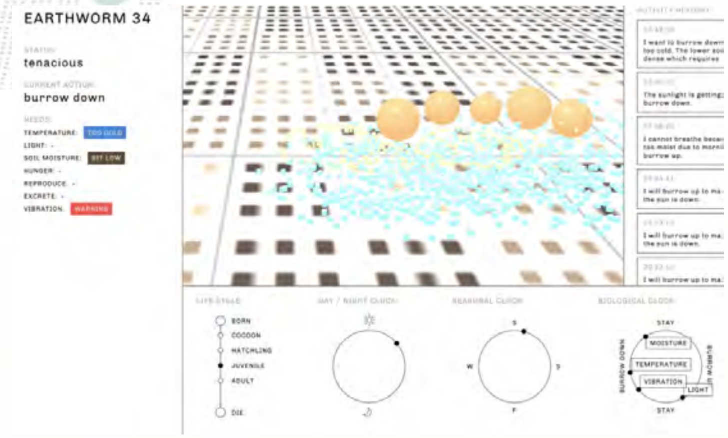
Spatial Interfacing: Views

Through the spatial interface, we reimagined how we understand forest space beyond the grid-based coordinates of computational agents. Instead of treating trees as points on a map, the interface reveals how different bodies create and experience space through their relationships and activities. Stakeholders can explore overlapping territories and zones of influence - from the extensive underground networks of tree roots and fungi to the movement patterns of insects and birds. The interface includes mechanisms for visualizing these fluid boundaries and interconnected spaces, showing how different bodies' spatial experiences intersect and influence each other. This helps stakeholders understand forest space not as a fixed grid but as a dynamic tapestry of overlapping territories and relationships.

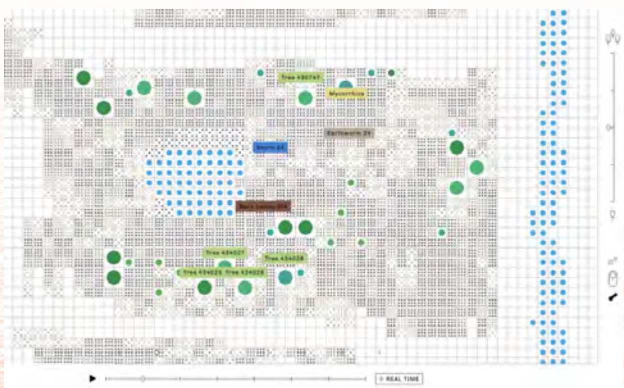


Stakeholders can observe the simulation results at the meso scale, where future scenarios are curated based on the status and interests of multiple species. The dashes and weights of the links illustrate the balance within the cluster.

The micro view presents detailed information about a single species, including its multiple temporal rhythms, spatial patterns, and activity history. The central panel features a real-time animation of the entity, dynamically visualizing data points as they emerge to illustrate the relationship between data and behavior.

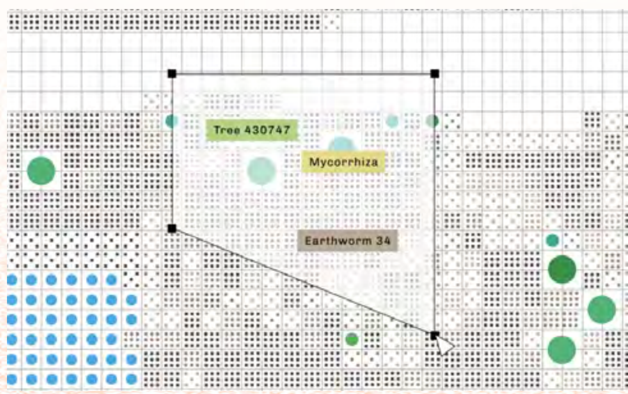


MACRO VIEW



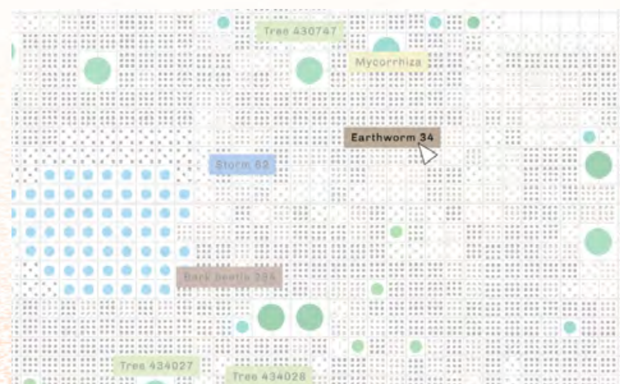
Stakeholders can observe the simulation results, allowing them to identify large-scale changes such as population dynamics, migration patterns, and ecological succession.

MESO VIEW



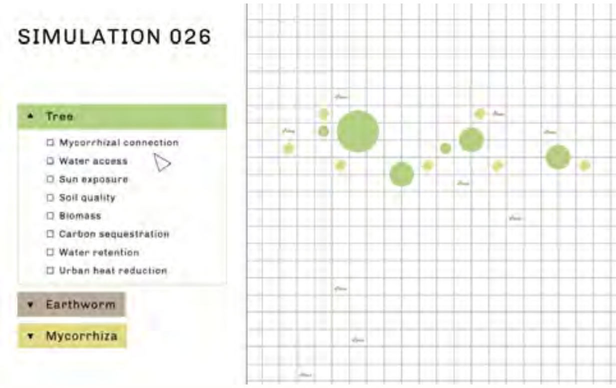
Stakeholders can draw a polygon to group entities, forming a dynamic community where each member plays a role in sustaining the community's survival.

MICRO VIEW



Each entity is labeled on the map. When clicked, it shows detailed information about the entity.

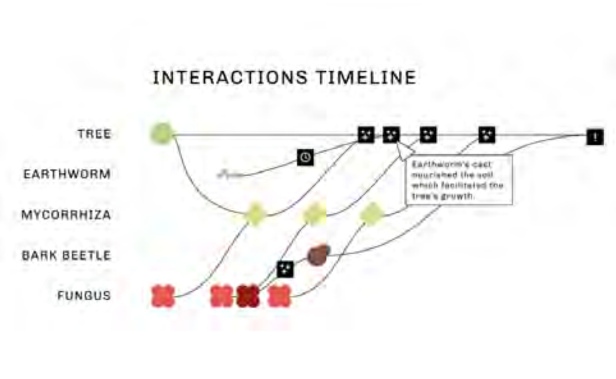
ATTRIBUTES



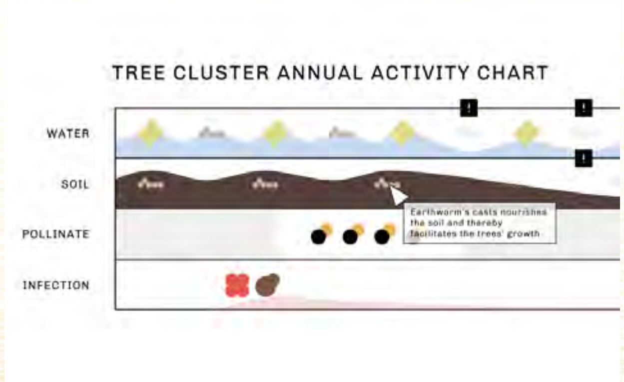
Stakeholders can choose the specific information they wish to observe in the simulation. The attributes of each agent are available in a drop- down menu.

When multiple data types are selected, they are shown as overlays.

RELATIONSHIPS

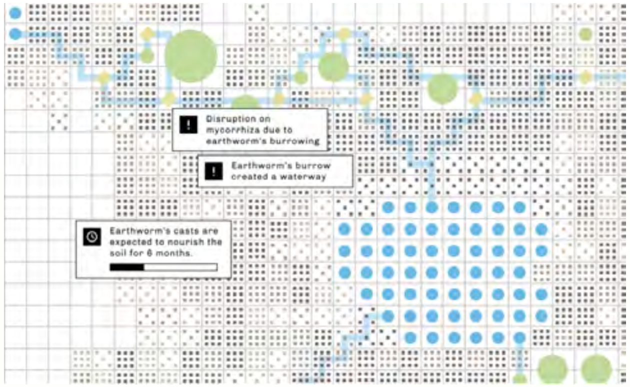


The interactions timeline highlights interactions between two or more entities. Each black box with an icon represents a different type of event: an exclamation mark indicates a warning, a clock signifies a fixed-time impact, and sparkles represent mutually beneficial interactions.



Cluster activity chart shows how its members contribute to the survival needs of the cluster. For example, the image above illustrates how different species are involved in providing water, nourishing soil, pollinating seeds, and infecting diseases.

EVENTS



The events that arise from interactions are positioned on the map.

Agential Interfacing: Clusters and Entanglements

The crafting of the agential interface moves beyond representing forest entities as individual agents with fixed attributes to reveal how agency emerges through relationships and interactions between the diverse attributes - the sensibilities and capabilities of multiple entities. Stakeholders can select and overlay different types of data, revealing how various forest entities interact across scales and times. The interface includes specialized visualizations like the cluster activity chart that shows how different species contribute to forest processes. An interaction timeline traces relationships between entities. These tools help stakeholders explore how forest phenomena emerge through complex intra-actions rather than existing as discrete, independent elements.

CONCEPTUALIZING DIFFRACTIVE INTERFACES

Our design exploration offers a way to bridge computational agents and more-than-human perspectives. While agent-based models typically represent forests as fixed entities with predefined attributes and behaviors, diffractive interfaces invite stakeholders to explore how these agents emerge through ongoing intra-actions with other entities across various scales. This shifts the focus from individual agents to the relationships and patterns that arise through different ways of cutting forest data together/apart.

We define diffractive interfaces as those that:

- Make explicit the agential cuts enacted through various ways of measuring and representing phenomena.
- Allow stakeholders to move between different cuts, revealing how measurement practices shape understandings of phenomena.
- Support exploration of relationships and entanglements that emerge from these different cuts.

In this approach, interfaces transcend their role as mere tools for accessing or visualizing data, becoming apparatuses that actively shape which realities are made observable and meaningful.

This fosters more relational and pluralistic engagements with forest simulation data, uncovering a plurality of agential cuts and revealing how entities and relationships come to matter, while also questioning the urban forest worlds these interfaces help to enact.

DISCUSSION

Diffractive Interfaces as a New Approach to Data Engagement

As data increasingly shapes our understanding of complex systems, there is a growing need for approaches that move beyond traditional, singular representations of data. Diffractive interfaces offer a new paradigm for engaging with simulation data by shifting from presenting a single "objective" view to enabling multiple, situated ways of knowing. This shift aligns with broader calls in HCI to embrace relational and pluralistic approaches to data practices [17, 22, 26, 32].

Computational representations should not be regarded as neutral reflections of reality. By foregrounding the partiality and situatedness of knowledge, diffractive interfaces open new possibilities for exploring data as dynamic and relational phenomena.

More-than-human Bodies as a Strong Concept

The concept of more-than-human bodies proved crucial in bridging between computational agents and forest entities. By highlighting how bodies simultaneously sense and are sensed, shape and are shaped by their environments, this concept offered a way to move beyond the fixed attributes and behaviors of computational agents. This contributes to ongoing discussions in HCI about designing with and for nonhuman actors [8, 20, 25] by providing a concrete framework for understanding how different entities experience and engage with their environments.

Mobilized as a "strong concept" [13], more-than-human bodies offered generative principles for interface design. The emphasis on temporal, spatial, and agential scales provided specific dimensions along which to develop interface mechanisms. This demonstrates how abstract theoretical concepts from more-than-human design can be translated into practical design guidelines.

Implications for More-than-human Design Practice

Using more-than-human bodies to inform interface design introduces significant methodological implications for design practice. Our work demonstrates the value of integrating theoretical concepts with technical expertise to guide interface development.

Specifically, our understanding of how agent-based models structure and represent forest data - through temporal steps, spatial coordinates, and agent attributes - enabled us to identify dimensions where more-than-human bodies could provide alternative perspectives. This interplay between theoretical framing and technical understanding allowed us to create interface mechanisms that both critique and extend existing computational representations. This approach highlights the potential for design methods that bridge theoretical concepts and technical implementation, rather than being driven by one at the expense of the other.

Limitations and Challenges

Our work also has several limitations. First, while the interfaces enable diverse perspectives on forest simulation data, they remain constrained by the underlying (infra)structures of agent-based models. Future research could explore alternative methods for data collection, modeling, analysis, and transformation to better support diffractive engagement and enable new forms of interaction and interface design.

Second, although the interfaces demonstrate how different "cuts" reveal various aspects of forest phenomena, they also expose tensions in balancing open-ended exploration with sufficient structure to make data meaningful. Simplified representations can facilitate immediate comprehension of predefined patterns, but they risk limiting stakeholders' ability to uncover unexpected connections or generate novel interpretations.

This challenge is particularly critical in the context of more-than-human design, where the aim is to support multiple ways of knowing rather than prescribing singular interpretations. Future work should explore how interfaces can scaffold understanding while maintaining openness, ensuring that stakeholders have the freedom to construct their own meanings and uncover relational insights.

This balance is essential for fostering pluralistic and nuanced engagements with data.

Finally, this work remains primarily conceptual, as the interfaces presented are not yet fully functional or deployed in real-world contexts. As such, the practical implications of our findings are currently suggestive rather than demonstrable. While a city planner, an urban ecologist, and a civic activist were consulted and a scenario-based expert review was conducted [18], future research involving working prototypes in situated contexts and with a broader range of stakeholders will be essential to translate these conceptual insights into practice.

Future Work

This work opens several promising avenues for future research. First, deeper interventions across different technical layers - ranging from data collection and modeling to analysis and transformation techniques - could broaden the scope of diffractive interfaces. While our research focused on interfacing with existing simulation data, future studies could investigate how alternative data infrastructures might better support diffractive engagement from the ground up. Exploring how to embed relational and multispecies considerations into the data lifecycle could further enrich this approach.

Second, there are opportunities to develop visualization techniques that balance structure with openness. These techniques could provide enough scaffolding to make data comprehensible while maintaining flexibility for emergent interpretations and discoveries. This might involve new ways of organizing information that guide users without constraining them or interaction patterns that foster both directed exploration and serendipitous discovery.

Lastly, while our work emphasizes enabling diverse ways of understanding forest data, future more-than-human research could explore how diffractive interfaces might support new forms of decision-making, negotiation, and governance that actively involve nonhuman stakeholders. This raises critical questions about how interfaces can translate multiple ways of knowing - human and nonhuman - into concrete interventions for cohabitation, mutual care, and collaborative survival. Such approaches would aim to empower all stakeholders, including other species by recognizing their agency and contributions to forest ecosystems, fostering relational and ecologically attuned decision-making processes that reflect the entangled nature of these environments.

CONCLUSIONS

This paper presents a design research journey into creating diffractive interfaces that support new ways of making sense of forest simulation data. By shifting from viewing data as a mirror of reality to actively exploring how different “agential cuts” produce varied understandings of forest phenomena, this work demonstrates a move from representation to diffraction, bridging research in HCI about the role of data in engaging ecosystems from a more- than-human perspective [9, 15] with studies on the material-discursive and performative dimensions of data practices [17, 22, 26].

The research journey unfolded in three key phases. First, our analysis of agent-based models revealed how computational representations structure our understanding of urban forests through temporal, spatial, and agential parameters. Second, we developed more-than-human bodies as a strong concept for reimagining how different entities might experience and engage with forest phenomena across these dimensions.

Finally, we translated these insights into interface mechanisms that enable stakeholders to enact different agential cuts across diverse temporal, spatial, and agential scales. This approach has broader implications for designing interfaces for complex systems. Instead of aiming for seamless, simplified representations that obscure computational processes, interfaces can foreground the agential cuts enacted by models, making the underlying assumptions, limitations, and biases explicit. By doing so, interfaces shift from being passive outputs of technical systems to active mediators that shape our interactions with and understanding of these systems.

Such interfaces are particularly relevant for addressing environmental challenges. The multiscalar, relational nature of ecological phenomena requires engaging with multiple ways of knowing. By making agential cuts more transparent and negotiable, interfaces can foster a reflexive and inclusive approach to environmental data and models, empowering users to explore alternative perspectives and generate new insights.

Looking forward, this work raises critical questions for future research. How can diffractive sensemaking be applied beyond urban forest management? What new interface mechanisms could empower stakeholders to create their own agential cuts? How might we balance structure and openness in interaction design to support both exploration and interpretation? Most importantly, how can interfaces enable action based on plural ways of knowing?

These questions highlight the rich opportunities for interaction design to support more-than-human ways of knowing through data, fostering more inclusive, reflexive, and actionable engagements with complex systems.

ACKNOWLEDGEMENTS

We would like to thank Bulent Ozel from Lucidminds AI for granting access to their computational model and for the many inspiring conversations, and to the various experts whose insights greatly enriched this work.

REFERENCES

[1] Karen Barad. 2007. Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning. Duke University Press.

[2] Nadia Campo Woytuk and Marie Louise Juul Søndergaard. 2024. Biomenstrual: Designing with the

More-Than-Human Body. In A.P. Rosén et al. (Eds.), More-Than-Human Design in Practice (1st ed.). Routledge.

[3] Marketa Dolejsova, Jaz Hee-jeong Choi, Andrea Botero, and Cristina Ampatzidou. 2022. Open Forest: Data, Stories, and Walking-With. PDC '22, Vol. 2. ACM, 309–312.

[4] Michael Dunbar and Chris Speed. 2024. Data Sets for Regenerative Futures: Cultivating Relational Ontologies. HttF '24. ACM, Article 39, 1–4.

[5] Jennifer Gabrys. 2022. Programming Nature as Infrastructure in the Smart Forest City. J. Urban Technol. 29(1), 13–19.

[6] Gabrys, J., Westerlaken, M., & Fatimah, Y.A. 2024. Actually Existing Smart Forests: A Proposal for Pluralizing Eco-technical Worlds. Environ. Plan. F, 0(0).

[7] Elisa Giaccardi, Johan Redström, and Iohanna Nicenboim. 2024. The Making(s) of More-than-human Design Hum.–Comput. Interact. 40(1–4), 1–16.

[8] Elisa Giaccardi and Johan Redström. 2020. Technology and More-Than-Human Design. Design Issues, 36(4), 33-44.

[9] Carlos Guerrero Millan, Sonja Rattay, and Youngsil Lee. 2024. A Manifesto for Other-Than-Human Imaginaries of Data. DIS '24 Companion. ACM, 253– 256.

[10] Lone Koefoed Hansen and Margrete Lodahl Rolighed. 2024. Encountering Human-Plant Relations: A Discussion on Interaction Design Can Encourage Human Sensibility to More-than-human Plants. DIS '24. ACM, 1400–1411.

[11] Donna Haraway. 2016. Staying with the Trouble: Making Kin in the Chthulucene. Duke University Press.

[12] Sara Heitlinger, Marcus Foth, and Rachel Clarke. 2024. Designing More-than-Human Smart Cities: Beyond Sustainability, Towards Cohabitation (Eds.). Oxford University Press.

[13] Kristina Höök and Jonas Löwgren, J. 2012. Strong Concepts: Intermediate-level Knowledge in Interaction Design Research. ACM Trans. Comput.- Hum. Interact. 19(3), Article 23.

[14] Sarah Homewood, Marika Hedemyr, Maja Fagerberg Ranten, and Susan Kozel. 2021. Tracing Conceptions of the Body in HCI: From User to More- Than-Human. CHI '21. ACM, Article 258, 1–12.

[15] Youngsil Lee, Larissa Pschetz, Mary Karyda, et al. 2024. Ecological Data for Manifesting the Entanglement of More-Than-Human Livingness. DIS '24 Companion. ACM, 377–380.

[16] Youngsil Lee, Chris Speed, and Larissa Pschetz. 2024. Pheno-Data: Using Tomatoes to Rethink Data and Data Practice for Ecological Worlds. Hum.– Comput. Interact. 40 (1–4): 249–71.

[17] Landon Morrison and Andrew McPherson. 2024. Entangling Entanglement: A Diffractive Dialogue on HCI and Musical Interactions. CHI '24. ACM, Article 493, 1–17.

[18] Seowoo Nam. 2023. Eco-Urban Futures: A More-Than-Human Approach to Multi-Agent Simulation for the Digital Twin of Urban Forests. MSc Thesis, Delft University of Technology.

[19] Iohanna Nicenboim, Doenja Oogjes, Heidi Biggs, and Seowoo Nam. 2025. Decentering through Design: Bridging Posthuman Theory with More- than-Human Design Practices. Human–Computer Interaction 40.1-4 2025: 195-220.

[20] Iohanna Nicenboim, Marie Louise Juul Søndergaard, Joseph Lindley, Anuradha Reddy, Yolande Strengers, Johan Redström, and Elisa Giaccardi. 2024. Unmaking-with AI: Tactics for Decentering through Design. ACM Trans. Comput.- Hum. Interact. 31, 6, Article 82, 20 pages.

[21] Catherine Phillips and Jennifer Atchison. 2018. Seeing the Trees for the (Urban) Forest: More-than-human Geographies and Urban Greening. Aust. Geogr. 51(2), 155–168.

[22] Courtney N. Reed, Adan L. Benito, Franco Caspe, and Andrew McPherson. 2024. Shifting Ambiguity, Collapsing Indeterminacy: Designing with Data as Baradian Apparatus. ACM Trans. Comput.-Hum. Interact. 31(6), Article 73.

[23] Shannon Rodgers, Kellie Vella, Bernd Ploderer, and Margot Brereton. 2023. Nature Fictions: Designing for a Sustainable Future Through Nature Relations. DIS '23. ACM, 1566–1580.

[24] Samson Roeland, Marco Moretti, Jorge H. Amorim, et al. 2019. Towards an Integrative Approach to Evaluate the Environmental Ecosystem Services Provided by Urban Forest. J. For. Res. 30, 1981–1996.

[25] Anton P. Rosén, Antti Salovaara, Andrea Botero, and Marie L. Juul Søndergaard, (Eds.). 2024. More-Than-Human Design in Practice. Routledge.

[26] Pedro Sanches, Noura Howell, Vasiliki Tsaknaki, Tom Jenkins, and Karey Helms. 2022. Diffraction-in- Action: Designerly Explorations of Agential Realism Through Lived Data. CHI '22. ACM, Article 540, 1–18.

[27] Martín Tironi, Marcos Chilet, Carola Ureta Marín, and Pablo Hermansen (Eds.). 2024. Design For More-Than- Human Futures: Towards Post-Anthropocentric Worlding. Routledge.

[28] Vasiliki Tsaknaki, Tom Jenkins, Laurens Boer, et al. 2020. Challenges and Opportunities for Designing with Biodata as Material. NordiCHI '20. ACM, Article 122, 1–3.

[29] Ron Wakkary. 2021. Things We Could Design: For More Than Human-Centered Worlds. The MIT Press.

[30] Ron Wakkary, Doenja Oogjes, Nazmus Sakib, and Armi Behzad. 2023. Turner Boxes and Bees: From Ambivalence to Diffraction. DIS '23. ACM, 790–807.

[31] Dong Wang, D., Pei-Yuan Xu, Bo-Wen An, and Qiu- Ping Guo. 2024. Urban Green Infrastructure: Bridging Biodiversity Conservation and Sustainable Urban Development Through Adaptive Management Approach. Front. Ecol. Evol. 12, 1440477.

[32] Michelle Westerlaken, Jennifer Gabrys, and Danilo Urzedo. 2022. Digital Gardening with a Forest Atlas: Designing a Pluralistic and Participatory Open-Data Platform. PDC '22 Vol. 2. ACM, 9 Pages.

[33] Michelle Westerlaken, Jennifer Gabrys, Danilo Urzedo, and Max Ritts. 2023. Unsettling Participation by Foregrounding More-than-Human Relations in Digital Forests. Environ. Humanit. 15(1), 87–108.