



Toward a Relational Materiality of Soils

Introduction

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Abstract As environmental matters, soils have been an object of inquiry primarily for the natural sciences, with social scientists and environmental humanities scholars occupied with the surface dramas of territory and its products. The invisibility of soils in much of public and intellectual life speaks not only to the literal invisibility of their subterranean elements but also to their taken-for-granted effectiveness as the material infrastructure of societies. Today's crisis of soil ecosystems calls for an urgent examination and improvement of human-soil relations. This is both an intellectual and a practical project. The authors believe that a crucial first step toward more just and sustainable human-soil relations is a critical reflection around soil knowledge practices and their onto-political effects. In this introduction, they open the field for such reflection by denaturalizing the category soil, discussing its complex materialities, its multiple scales, and the diversity of existing soil ontologies and epistemologies. In so doing they argue for a relational materiality approach to the study of soils. The authors place this relational materiality approach within a practical, political, and ethical project of re-embedding societies in soils and lands. Finally, they indicate emerging arenas of inquiry where a relational materiality approach to soils is needed.

Keywords soil, relational materiality, ontological politics, Anthropocene, environmental ethics

I would not dare,
now, to say I knew anything of land. It has no master;
only people who strive to learn and understand
the minutes of it, and the hours. The earth moves faster
than we can comprehend, so seek a segment, find a strand
of it that you can love.

—Adam Horovitz, “I Believed I Understood the Land,” from the collection *The Soil Never Sleeps*

Soil, the Forgotten Element

Soils are the most important thing that we rarely think about. Within the social sciences and humanities, soils (as opposed to land) have attracted little attention in comparison with burgeoning literatures on for example water, forests, or biodiversity.¹ In contrast with these, until very recently soils were predominantly approached as environmental matters, an object of inquiry primarily for the natural sciences, with social scientists and humanities scholars occupied with the surface dramas related to territory, water, minerals, and crops.² The relative invisibility of soils both in academic and public life speaks not only to the literal invisibility of their subterranean elements, but also to their taken-for-granted effectiveness as the material infrastructure of social life.³

In a time of anthropogenic ecological destruction and linked societal crises, we urgently need greater attention to soil and land from all quarters. Soils are indispensable to terrestrial socioecologies as they participate in and drive nearly all biological and chemical processes that make the Earth's non-aquatic surface habitable.⁴ The degradation of soil ecosystems everywhere through pollution with chemicals and plastics, salination, sealing, creeping erosion, and loss of organic matter illustrates a very real breakdown of the crucial relation between humans and soils.⁵ We agree with Shiva that there is no alternative for human flourishing then to reconstruct this relation in a socioecologically sustainable way.⁶ Bringing more attention to human-soil interactions, and building sustainable soil futures, are, we believe, important intellectual and practical tasks for social sciences and environmental humanities alike.

We are therefore delighted to present this special section's collection of articles, which illustrate and critically engage diverse forms of human-soil relations. We believe that the crucial first step toward a more just and indeed sustainable human-soil relations is a critical reflection around soil knowledge practices and their onto-political effects. In this introductory essay, we thus seek to denaturalize the category soil by briefly discussing its complex materialities, its multiple scales, and the diversity of soil

1. Notable exceptions include the authors whose work we review in this essay. Other exceptions include work in political ecology on soil erosion (e.g., Blaikie, *The Political Economy of Soil Erosion in Developing Countries*) and environmental history (e.g., McNeill and Winiwarter, *Soils and Societies*, and McNeill and Winiwarter, "Breaking the Sod"), especially work on the dust bowl (e.g., Worster, *Dust Bowl*). See also the recent collection by Salazar et. al. *Thinking with Soils*, which resonates strongly with this special section.

2. For a review of surface approaches to the question of soils, see Krzywoszynska, "Caring for Soil Life in the Anthropocene."

3. Puig de la Bellacasa discusses soil as infrastructure in "Encountering Bioinfrastructure."

4. Wall notes there is now a wide appreciation in natural sciences that soils are a foundation of human and ecological survival in *Soil Ecology and Ecosystem Services*. Lin similarly argues that soils create a life-sustaining environment thanks to their functioning as a "geomembrane across which water and solutes, as well as energy, solids, and organisms, are actively exchanged among the atmosphere, the biosphere, the hydrosphere, and the lithosphere" in "A New Worldview of Soils," 1832–33. See also Hillel, *Out of the Earth*.

5. Food and Agriculture Organization of the United Nations, "Status of the World's Soil Resources."

6. Shiva, *Soil not Oil*.

ontologies and epistemologies.⁷ In so doing, we argue for a relational materiality approach to the study of soils. We place this relational materiality approach within a practical, political, and ethical project of re-embedding societies in soils and lands. Finally, we indicate some emerging arenas of inquiry where a relational materiality approach to soils is needed. We then present an overview of the essays in this special section and offer some concluding remarks.

The Diversity of Soil Epistemologies and Soil Ontologies

Soil, or the “ecstatic skin of the earth,” as the arborist Logan calls it, is made through interactions between geological, biological, and social processes.⁸ The materials and organisms in soil are so tightly coconstituted that there are no obvious ways of distinguishing where one entity ends and another begins. Bring to mind the tip of a tree root, with its complex associations of fungal hyphae, bacterial colonies, roots of other plants, with its immersion and participation in hydrological, atmospheric, and mineral media. Where does a tree root end and a soil begin? The answer is far from given, and where the cuts are made has onto-political effects (Barad 2007). Soils’ textural, chemical, and biological diversity is astounding; for example, it is estimated that only 1 percent of soil microorganism species have been identified.⁹ Soils’ complex materialities matter at a number of scales, from the micro processes at the scale of individual soil aggregates to the hydrological processes within watersheds to global scale interactions between soils, atmospheres, and oceans. How humanity interacts with soils thus has similarly multiple scalar implications.¹⁰

Soils’ great material and scalar complexity further interacts with a diversity of soil knowledge and practice systems. The ways communities conceive soil natures is not determined but differs between contexts, emerging in dialogue with deeply held social and cultural concerns. Studies in ethnopedology have amply illustrated the great variety of soil knowledge and classification systems and the numerous ways in which soils are brought into social relations.¹¹ For example, the indigenous Purepecha communities of central Mexico treat soil as a dynamic subject that moves and behaves. Their relations with land are not based on a management of an inert asset but unfold as a dynamic relationship in which the needs of the land are contextually responded to.¹² For Colombian smallholders in the Amazon, growing crops implies cultivating a place-specific sensibility to the taste, smell, and touch of the earth.¹³

7. Throughout the article, where stylistically appropriate, we refer to *soils* as a plural noun. This reflects our commitment to stressing the diversity of soil materialities; this convention is something we further share with many soil scientists.

8. Logan, *Dirt*.

9. Orgiazzi, Bardgett and Barrios, *Global Soil Biodiversity Atlas*.

10. Schulte et al., “Making the Most of our Land.”

11. See, e.g., Barrera-Bassols and Zinck, “Ethnopedology.”

12. Barrera-Bassols and Zinck, “Land Moves and Behaves.”

13. Lyons, “Soil Science.”

The diverse ways in which knowledge, meaning, and ethics regarding soils interweave in modern industrial farming in the so-called West has been less explored.¹⁴ However, even in this context Wahlhütter and colleagues found that for Austrian farmers, soil qualities are a manifestation of their own moral rectitude and cultural capital. In her work on sustainable soil management in England, Krzywoszynska found that not tilling the soil demands new forms of “good farmer” identity. Similarly, in Switzerland Schneider and colleagues found that soil aesthetics play a key role in farmers’ perceptions and communication of good soil management practice.¹⁵ As industrial management techniques are reconsidered, new ways of knowing develop alongside new forms of practice in the field.

This diversity of soil epistemologies and ontologies is not reserved to grower communities. For soil scientists, the definition of what a soil is has changed historically and continues to be debated.¹⁶ Hartemink’s fascinating review of the changing definitions of soil since the nineteenth century highlights the context-dependence of soil epistemologies and ontologies, with new conceptions of and investigative practices emerging in relation to particular technological and political developments in soil sciences. For example, the rise of centralized land governance generated a new need for soil mapping and classification.¹⁷ Hartemink indicates that today, multiple, discipline-specific definitions of soil coexist.¹⁸ Various scientific definitions of soil can therefore be seen as culturally, contextually, and historically specific ways of making sense of soil matters, although such a perspective continues to be resisted by many soil scientists.¹⁹ The applicability of the powerful certified soil knowledge systems, developed largely in Euro-Asia, to non-Western geographical contexts is starting to be contested as they clash with locally desirable socioecologies.²⁰ As Lyons reports, a critical Colombian farmer ironically referred to industrialized land management strategies as an agriculture of death, while India’s leader of Zero Budget Natural Farming Palekar urges his followers to renounce Western agronomic science as based on the lies of the father of chemical agronomy “Liebig—Lie-Big.”²¹ In Indonesia, the divergent expertise of nonmainstream knowledge producers is being used to legitimize the ongoing destruction of peatlands for palm oil production, contrary to the advice from the scientific mainstream.²²

14. Hall, “The West and the Rest.”

15. Wahlhütter, Vogl, and Eberhart, “Soil As a Key Criteria”; Krzywoszynska, “Making Knowledge and Meaning”; Schneider et al., “Soil Conservation in Swiss Agriculture.”

16. For insights into the complex history and contested present of soil science, see the collection by Warrentin et al., *Footprints in the Soil*.

17. For an interesting discussion of the relations between soil mapping and land governance in the context of racist land politics, see Van Sant, “The Long-Time Requirements of the Nation.”

18. Hartemink, “The Definition of Soil since the Early 1800s.”

19. Krzywoszynska has had personal experience of such resistance during debates she had at the 21st World Congress of Soil Science in Rio, August 2018; see also Engel-Di Mauro, *Ecology, Soils and the Left*.

20. E.g., Richelle et al., “Looking for a Dialogue”; Lyons, “Soil Science.”

21. Lyons, “Soil Science”; Münster, “Gut and Soil.”

22. Goldstein, “Knowing the Subterrean.”

Toward a Relational Materiality of Soils

These contested knowledge politics of soils indicate an urgent need for more nuanced and contextual understandings of human-soil relations, both within natural sciences and in social sciences and environmental humanities. In this collection, we call for a relational materiality approach to the study of soils across disciplines. We call for forms of soil investigation and action that acknowledge symmetrically the emergent biophysical agency of soil ecosystems, their sociocultural constitution, and the dynamic interactions between those factors. Intellectual and practical engagements with soils need to go beyond the surface perspective, which has manifested in soils being approached primarily as land and landscape in social sciences and humanities.²³ We are calling here for an understanding of soils as dynamic ecologies in the becoming of which human beings are implicated, with whom they are shaped, and on which they depend. Such a relational approach to soils requires attending to relations rather than predetermined essences in conceptualizing the constitutions of soils as sociobiophysical objects, and relations between soils and humans.

At the heart of this research agenda are soils' ontological politics—the question of what soil realities get enacted, and which get silenced or never come into being.²⁴ As critical scholars pursuing socioecological justice, our task is to remain attentive to and critically engaged with such emerging soil ontologies, the knowledge politics that underpin them, and their world-making consequences.

This call to soil relationality resonates with the broad relationality project within social sciences and environmental humanities, a shared commitment to challenging and undoing the analytical separation between nature and humanity.²⁵ We argue that taking relationality seriously has a particular importance in the case of soils, as building sustainable soil relationalities may open a route toward a practical and life-restoring onto-politics across scales. Negating the relationality of soils continues to enable widespread destruction of socioecosystems, pushing vital soil ecologies and the populations of humans and non-humans who depend on and develop with them beyond recovery. This surface perspective on soils can be read as a version of the myth of globe-spanning

23. Engel Di-Mauro in “Learning Dialectics to Grow Better Soils Knowledge” argues that there is a lack of a relational perspective on soils in natural sciences, both through a lack of reflexivity about conditions of knowledge production, and through a down-playing of relational processes of soil formation and destruction in favour of static categories. His proposed relational approach to soils is informed by materialist dialectics, and seeks to unite socio- and biophysical relationalities. For a further critique of static and surface ontologies of soils from a political ecology angle, see Münster and Poerting, “Land as Resource, Soil, and Landscape,” and from a practitioner angle, see Krzywoszynska et. al. “To Know, to Dwell, to Care.”

24. Mol, “Ontological Politics.”

25. Our thinking has been particularly influenced by the work of Barad on intra-action in *Meeting the Universe Halfway*, Haraway's worlding in *Where Species Meet*, Moore's double internality in *Capitalism in the Web of Life*, Latour's actor-networks in *Reassembling the Social*, and Swynedouw's socationatures in “Modernity and Hybridity.”

universality Latour discusses in *Down to Earth*. He argues that as the climatic changes of the Anthro(po)scene shatter universalist illusions, populations find themselves faced with the task of returning to soil in order to survive and to thrive. However, he argues, it is wrong to talk of a return as the soil/land which could support us acquires new characteristics, pulling us into an inextricable relationality with it. This soil-as-attractor “inherits materiality, heterogeneity, thickness, dust, humus, the succession of layers, strata, the attentive care that it requires. . . . The ground, the soil, in this sense, cannot be appropriated. One belongs to it; it belongs to no one.”²⁶

This need to create new forms of dwelling—of place-specific knowledgeable action that would bring together the above- and belowground and human and ecological dynamics—suggests to us a shift from the governance of land to the governance of soil, not as the top-down management of a passive surface for human intentionality to play out on but as a dynamic process of re-inhabiting diverse socioecologies.²⁷ We agree with Latour’s contention that humanity needs to land, and that for this landing to be successful, social and ecological relations need to come together in particular places. This coupling requires a valorization of local knowledge systems, land justice, and communal participation in socioecologically sustainable land use or, rather, dwelling. We believe a rebuilding of socioecological relations from the ground up is crucial within and beyond the humanities and social sciences. We hope this project will be an opportunity to foster a critical interdisciplinarity of soils, connecting excellent research on land justice and land governance with qualitative methodologies and important natural science inquiries into dynamic soil properties.²⁸ We invite a broad opening of the matter of soils, investigating the processes through which soils become or fail to become objects of specific epistemological, ontological, and ethical concern. Moreover, we advocate intervening in these processes through both critique and active involvement, as both an urgent and a hopeful task.

At the same time, this work brings the study of soils to emergent explorations of the unstable boundary between the over- and underground. Stuart Elden, for example, has called for critical considerations of height and depth as well as area in analyses of borders and security.²⁹ These questions have been developed by scholars like Stephen Graham in relation to the built environment; Philip Steinberg and Kimberley Peters in the realm of oceanic geographies; and political ecologist Jenny Goldstein in her studies

26. Latour, *Down to Earth*, 92.

27. On dwelling as knowledgeable action see Ingold, *The Perception of the Environment*. For an elaboration of the concept of dwelling in relation to soil knowledge see Krzywoszynska, Banwart, and Blacker, “To Know, to Dwell, to Care.”

28. A good example is the work by Stocking and Murnaghan on conceptualizing, measuring, and acting on land degradation by starting from the perspective of subsistence farmers in *A Handbook for the Field Assessment of Land Degradation*.

29. Elden, “Secure the Volume.”

of satellites in peat forest conflicts.³⁰ Robert MacFarlane's *Underland* illuminates emergent confrontations with the subterranean, exploring the literal upending of human understandings of our planet in a moment of deep ecological change. Analyses of the social life of soils are essential to such complex understandings of territory in its broadest aspects.

In the following section, we point to some important areas of soil-human relations that invite relational materiality approaches. Overall, we suggest that scholars of soils' relational materiality critically investigate the processes through which unjust and destructive human-soil relations are created and reproduced. We identify the processes of capital investment, governance, and quantification as crucial for the emergence of particular soil relational materialities, calling for further scholarly attention. We further argue that researchers should document and valorize processes that give rise to socioecologically sustainable human-soil dynamics. We also call for a greater experimental engagement with soil sense-abilities to develop new processes of sensing and making sense of soils. We see all of these arenas as ripe for and necessitating interdisciplinary collaboration.

Soil Relational Materiality: Toward a Research Agenda

A crucial area for investigation in human-soil relations today is the role that capital plays in bringing particular soil relational materialities into being.³¹ One significant area is the rising attention to soils as repositories of exploitable and potentially modifiable genetic material. Soils' incredible biodiversity is increasingly explored through new metagenomics technologies, flooding researchers with data of potential commercial value. As one soil scientist told us, "Every time we sequence bulk genome from soil we discover thousands of new species of bacteria."³² For some scientists, the potential of soil microbiome modification/engineering promises to finally overcome the tension between productivist and ecological objectives in farming, bringing about a new era of microbiome-based agro-ecology.³³ For individual farmers, metagenomics analysis may offer new ways of engaging with soil ecologies beyond nutrient levels and pathogen loads.³⁴ The political economies and political ecologies of soil microbiopolitics—the contestations around the appropriate ways of relating to microbial entities in human projects—will be a crucial arena for future research.³⁵ More than that, projects that

30. Graham, *Vertical*; Steinberg and Peters, "Wet Ontologies, Fluid Spaces"; Goldstein, "The Volumetric Political Forest."

31. For a relational materiality discussion of soil resource-making see Krzywoszynska, "Nonhuman Labor and the Making of Resources: Making Soils a Resource through Microbial Labor," in this issue.

32. Prof. Jonathan Adams, presentation at "Dirt Science: An Introduction to Soil Systems," 26 September 2017, Cranfield University.

33. Granjou and Philips, "Living and Labouring Soils."

34. See, e.g., the Big Soil Community initiative in the UK (info.fera.co.uk/bigsoilcommunity/) and forthcoming publications on this topic by Outhwaite and Krzywoszynska.

35. Paxson, "Post-Pasteurian Cultures."

investigate soil microbiome materialities and agencies as emergent from, relational to, and acting upon such microbiopolitical concerns are needed.³⁶

As the urgency to act on (or be seen to act on) climate change becomes more acute in the policy and business arenas, processes of governance are giving rise to particular forms of soil relations. Here, the capacities of certain soils as potential carbon capture mechanisms are being linked with land management practices (such as farming systems or environmental management) so as to increase stocks of soil organic carbon.³⁷ Such carbon-driven land-use change is being heavily promoted by global and increasingly national policy makers, supranational bodies such as the World Bank, and influential campaign groups.³⁸ Perhaps the most notable campaign is the 4/1000, which is calling for action at all levels to increase soil carbon stocks by 0.4 percent annually in order to counteract the effects of anthropogenic carbon dioxide emissions.³⁹ This emergent carbon ontology of soils, in which soils are primarily understood through their capacity to hold on to atmospheric carbon, resituates local soils as global climatic and ecological actors. This impacts local land management strategies, which are intimately linked with livelihoods and well-being in ways that are easily left unaccounted for in globally scaled assessments of carbon capture, creating problematic tensions between carbon accounting logics and local systems of soil knowledge and valuation.⁴⁰ The ways in which the carbon ontology of soils may be developed and used to pursue oppressive or, alternately, just human-land relations is another crucial area for greater investigation.

Beyond soil carbon and metagenomics, new relational materialities of soils are coming into being in the context of projects that seek to *account for* and *ascribe new value* to soils in ways that would make them compatible with policy and business frameworks.⁴¹ Crucial to these processes are the performative effects of soil qualification through soil metrics and soil assessment, and their contested knowledge politics. The relational dynamics between soil properties (measured soil characteristics) and soil quality (situated judgements about the value of those characteristics) performed in

36. On methods and approaches for studying human-microbiome relations see Evans et al., "Microbial Multiplicity."

37. The negative contribution of soils to climate change from melting permafrost soils releasing methane is more rarely discussed.

38. See, e.g., World Bank, *Carbon Sequestration in Agriculture*; Lefèvre et al., *Soil Organic Carbon*.

39. www.4p1000.org/; the initiative is both extremely influential and hotly contested in the scientific community, see, e.g., Minasny et al., "Soil Carbon 4 per Mille," and the subsequent debate in the journal *Geoderma*.

40. These tensions are explored by Brockett in relation to wet soil management in the UK in her PhD thesis, "An Interdisciplinary Approach to Mapping Soil Carbon." The trade-offs between carbon storage and other soil functions are explored by O'Sullivan et al., "Functional Land Management for Managing Soil Functions." Ingram et al. note the resistance to what we are calling the carbon ontology of soils in European farming communities in "Communicating Carbon Soil Science to Farmers."

41. See, e.g., Davies, "The Business Case for Soils," where she argues for a valuation of soils in supply chains. In policy, see UK's Department of Food and Rural Affairs' *Our Green Future*, which promises a soil health index as a new policy mechanism.

practices of soil assessment always imply desired land uses. However, these ultimately political decisions are often obscured by the seeming value-neutrality of scientific practices.⁴² As Engel-Di Mauro comments in relation to certain existing scientific soil quality definitions:

There are many problems with these views on soil quality and they largely stem from *subsuming political questions under external biophysical processes* [emphasis added]. There is no relational understanding (high soil quality for one species can be poor soil quality for another), no discussion of the social context of soil quality knowledge production, no consideration for the possibility of contradictions between human species-specific needs (or even those of other species) and overall biomass productivity, no explication about what count as legitimate uses of soil (who is to decide on land use and management, for instance), no regard for conflicting soil uses, and no recognition of boundaries as socially constructed rather than given.⁴³

The importance of these processes of soil quantification to the realities of on-the-ground land use, including planning, practice, dwelling, and habitation, cannot be overstated, as they may become oppressive instruments of governmentality and eco-governmentality.

The dominance of particular scientific framings in relation to practices of soil valuation and land use and their frequent implicit (or explicit) support of socioecologically destructive land use practices under capitalism make the study of non-mainstream/non-certified soil knowledges a particularly important point for critical intervention.⁴⁴ Due to the dominance of natural science framings of soils, other languages, sensibilities, and practices of relating to soils have become dormant or even disappeared. There is therefore an opportunity and a need to experiment with a variety of tools for making soils senseable—available to the senses and to sense-making of humans—in order to forge new attachments and explore other relationalities. Future research into non-mainstream soil knowledges should consider both a valorization of existing soil knowledge systems and an experimentation with new forms of building human-soil relationalities.⁴⁵

Although not discussed specifically in those terms, the mutual tuning of human and earthworm bodies described by Bertoni is a good example.⁴⁶ Bertoni argues that following processes rather than simply following entities demands a radical recognition of modes of relating fundamental to those entities; in the case of earthworms, eating

42. Susanne Friedberg's work on the politics of metrics is relevant here. See, for example, Friedberg, "Footprint Technopolitics."

43. Engel-Di Mauro, *Ecology, Soils, and the Left*, 47; our emphasis.

44. On the relationship between capitalist land use and local agrarian knowledge see Schneider and McMichael, "Deepening, and Repairing, the Metabolic Rift," 480.

45. See, e.g., Bawaka Country et al., "Working with and Learning from Country."

46. Bertoni, "Soil and Worm."

emerges as a key mode of relationality. What other modes of co-being may emerge as we follow soil entities and soil processes, with the aid of science, technology, and art-enhanced apparatuses?⁴⁷ How may those processes of creation/discovery be made significant for localized practices of building sustainable human-soil relations? These experiments could, for example, aim to make meaningful connections between valued surface manifestations of soil's capacities—plant and animal growth, landscape beauty, habitation—with the invisible dynamics of soils, both through artistic interventions and by embedding attentiveness to soils into everyday practices of land use. We see a role for scientific inquiry in developing knowledge tools and practices that would empower and enable various soil workers, soil users, soil citizens—what we could call *soil publics*—to explore *their* soil relationalities. Such sense-abilities should make the best of scientific forms of soil investigation while opening up techno-scientific tools and practices to such publics. There is a huge role here for reflexive forms of scientific soil inquiry, and for a close collaboration between soil sciences and soil publics in order to enhance the sense-ability of soil-relating humans to soils; to open up and multiply conversations about what desirable soil relational materialities may look like; and to prevent the inadvertent obfuscation of ultimately socioecologically destructive ontologies.

This Collection

In this collection of articles we aim to take the first steps toward a productive and radical opening up of soil materialities. As noted, we see engaging critically with soil knowledge practices and politics as the crucial first step toward the opening up of soils' natures. As a result, the essays collected here engage primarily with the rise and contestations of the modern and Western soil ontologies whose practical and conceptual dominance continues to challenge efforts at developing more diverse and socioecologically just human-soil relations. The essays in particular focus on the power of institutionalized knowledge and of capital in their shaping and upholding of particular relational materialities of soils. These powers and their contestations matter in complex ways to the emergence, shaping, and silencing of soils' qualities and capacities.

A person whose work has come to symbolize a radical shift in human-soil relations is Justus Von Liebig, a nineteenth-century German chemist and the so-called father of modern agricultural science. His work on plant growth was revolutionary in that it drastically simplified the question of how to enhance yields to the interactions between plants and chemicals. Removing a preoccupation with soils as complex and heterogenous living systems, Liebig's ideas gave rise to a powerful and persisting ontology of soil as an inert repository of plant nutrients. This, Greta Marchesi argues in her essay, laid the foundation of a geographically universalizing agronomic science, which

47. Such potential for forging animated as opposed to passive imaginaries of soils through scientific and artistic visualisation is explored by Puig de la Bellacasa in "Re-animating Soils."

could in turn support the geographical expansion and intensification of capitalism in the same period. Leibig's contribution to the creation of the chemical ontology of soils, she shows, was therefore crucial to the emergence of the new capitalist ecological regime. What enabled Leibig's vision to become so firmly embedded in today's soil epistemologies and ontologies, she further illustrates, was his commitment to the professionalization and institutionalization of soil knowledge. This double coupling of the chemical ontology of soils with the operations of capital, and with the professionalization of agrarian soil knowledge, continues to uphold the metabolic and epistemic rift between soils and soil publics.⁴⁸

Anna Krzywoszynska's essay further explores the continued cocreation of agrarian capitalism and soil ontologies through a focus on the changing character of soil labor. Inspired by new scientific perspectives on soils that increasingly stress their living component, especially soil microbes, farming communities are similarly attending to soil biota. This attentiveness is producing a practical and conceptual shift in the way that human-soil relations are imagined and performed in modern, conventional farming, as the capacities of soil biota become valorized and responded to in a number of ways. However, Krzywoszynska argues, these emerging human-living soil relations also reproduce the established logic of improvement, that is a material transformation of soils in line with the demands of agrarian capitalism. While the nature of soil labor may be changing from the human labor of farmers and tractors and chemicals to the nonhuman labor of soil biota, the objectives of this labor, and so the ontological assumptions around what (and whom) soils are for, remain largely unchallenged. The capacities of soil biota as geo-forming actors, Krzywoszynska further suggests, may further result in soil biota becoming agents of a wider improvement of nature beyond the spaces of food production.

Whereas Anna Krzywoszynska's essay explores the emergence of new relational materialities of agrarian soils, Germain Meulemans looks at the changing materiality of soils in the urban context. Engaging with the history of modern urbanism, he argues that a conceptual and practical disappearance of soils—their backgrounding—was central to the emergence of a modern city. The sealing and waterproofing of soils with man-made materials such as asphalt and concrete made soils both invisible to urban dwellers, and made a preoccupation with urban soils an exclusive responsibility of specialists. He further shows that current experiments with urban soils amongst engineers, while in keeping with established objectives of technocratic urbanism, are also producing a dynamic relationship between soils and humans that goes against their usual representations as static resources as soils become the very object of infrastructure engineering rather than something that only underpins it. These trends go against the typical exclusion of humans as agents of pedogenesis (soil making), and invite new ontologies of soils as products of human and non-human processes. As in Krzywoszynska's essay, Meulemans also notes, however, that these new capacities of soils as dynamic

48. See also Schneider and McMichael, "Deepening, and Repairing, the Metabolic Rift."

and changeable seem to bolster rather than challenge anthropocentrism in human-soil relations, extending the modernization project underground.

What principles may guide us in challenging these historic and contemporary separations between humans and soils, and in developing practices of soil connection and soil care? In her essay, Anne O'Brien argues that soil imaginaries are key to the formation of caring and respectful soil relationalities, as through these imaginaries "new dimensions of soil flourishing become evident, and the distress of soil ecosystems is rendered ethically acknowledgeable." To enable this, she introduces the concept of soil integrity, understood in a processual mode as "a property of interspecies relationships between plants, microbes, and invertebrates." Whereas body metaphors used in farming and scientific discourses in relation to soils make room for and elicit affective engagements with soils as vulnerable and living, O'Brien suggests integrity can be productively divorced from notions of bodily boundedness and individualism. Integrity of soils as relations, as meshworks and food-webs expressing their diverse capabilities, makes it possible to speak of justice in relation to soils. O'Brien's essay further points to the need for greater attentiveness to soils' teleologies and for more-than-scientific descriptions of soil engagements so as to create "a compelling aesthetic vision of shared conviviality across species."

Concluding Remarks

Engaging with soils as crucial, ethical, and relational materialities grounds in a very practical way the sometimes abstract critiques of nature-culture dualisms, and the calls for a greater recognition of the material embeddedness of societies. The unique nature of soils as both ecology and land demands deeply socioecological approaches to sustainability. As this introduction and the collected essays explore, due to soils' holistic nature the political decisions about land use are inseparable from strategies for socioecological survival. We see reconnecting with soils as part of a broader project of conceptually and practically responding to the inescapable relationality of human life, a relationality that includes humans and nonhumans. Our relation to land is deep; our roots are deep in the soil, simultaneously culturally and materially. Caring for and about soils is thus not external. Caring for soils is about caring for particular ways of being human.

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