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Nonhuman Labor and the Making of Resources

Making Soils a Resource through Microbial Labor

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Abstract With soils increasingly seen as living ecosystems, the understanding of the relationship between soils and agricultural labor is changing. A shift from *working the soil* to *working with the soil* is hoped to deliver a true ecological modernization of capitalist agriculture, making the production of ever-growing yields and the maintenance of healthy ecosystems co-constitutive. Drawing on ethnographic data from English farming, this article argues that the current trends are in fact a continuation of the logic of capitalist soil improvement in which soils are made into economic resources. By proposing a new conceptualization of labor as a material process of transformation oriented toward the generation of capital value, the author establishes a dialogue between hitherto separate literatures on the making of economic resources and on nonhuman labor. This approach transforms the debates on the relationship between nature and capital by productively collapsing the distinction between labor and resources. The author argues that acknowledging the material co-constitution of (any form of) labor and resource making allows us to better analyze the processes through which natures are rolled into capital. Today's enrollment of soil biota as labor thus opens up the whole biosphere to the logic of improvement, and to the operations of capital.

Keywords nonhuman labor, soil, microbes, resources, farming

Setting the Scene

This article grows out of a moment of profound cognitive dissonance. In 2017, I was watching the proceedings of the Oxford Farming Conference, a significant event in the UK's conventional or otherwise mainstream agricultural producers' annual calendar. The conference often features speeches by British ministers and royalty, and is sponsored by some of the biggest agrochemical, crop research, and machinery manufacturing companies. However, in 2017, a quarter of its program was taken up by Soil Saviors, a panel that featured, among others, George Monbiot, a British environmentalist and writer and one of the most vociferous and unremitting critics of the

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dominant agro-food regime. The short video that introduced the session presented soils as *simultaneously* natural ecosystem *and* productive resources.[1] There was no hint of the key tension that continues to characterize agro-environmental politics and governance: between productivist objectives, aimed at maximizing agricultural outputs out of nature for the generation of profit, and environmentalist objectives, which aim to protect said nature from degradation through exploitation. In the establishing shots, the camera swept over pristine rain forests, untouched cedar groves, cloud-bathed canopies—the natural world in all its awe-inspiring beauty. As we watched a majestic tree being felled, a deep male voice expressed concern over the degradation of natural resources through human over-use. This degradation was immediately linked with concerns about the future of agricultural productivity. Interviews with UK farmers who farm in a modern, intensive way, albeit without ploughing the ground, followed. These established a relation between falling yields, falling productivity, and the degrading quality of soils. Changing the ways soils were worked from ploughing to noninvasive methods (such as no-tillage) were presented as a route to simultaneously enhancing the productivity of soil, and to protecting both it and the other natural resources of which it is a foundation. By changing the way soils are worked and worked with, the video was suggesting, soils can not only be conserved as finite resources but also can be made more *resourcefull* (hereafter *resourceful*)—more productive, more resilient, and in other ways better aligned to the demands of modern farming under capitalism. Win-win.[2]

Ecological Intensification and the Changing Processes of Labor

This narrative of ecological intensification of soil, in which increased yields and/or crop productivity are achieved through environmentally beneficial processes, centers on current and aspirational changes to the material processes of soil labor.[3] Soil labor is transformed from an activity carried out predominantly by human bodies to an activity carried out by the soil biota under human management. This transformation of labor, it is hoped, will enable policy, grower, and scientific communities to restore soil ecologies and so respond to the global soil crisis without challenging the agro-productivist status quo.[4] Scientific research has highlighted the role that soils play "beyond the field fence"

1. The *OFC 2017—Soil Saviours* video is available at vimeo.com/198187224 (accessed November 19, 2018).

2. www.soilcapital.com/.

3. Ecological intensification is a variant of sustainable intensification of agriculture. In sustainable intensification, the objective is to minimize environmental harm while increasing crop productivity (see. e.g., Godfray, "The Debate over Sustainable Intensification"). Ecological intensification seeks to enhance environmental benefits as well as productivity by replacing anthropogenic inputs with "ecosystem services" (see e.g. Bommarco, Kleijn, and Potts, "Ecological Intensification").

4. On the idea of a global soil crisis, see Koch et al., "Soil Security." For a discussion of the changing meanings and configurations of agricultural productivism, see Wilson and Burton, "'Neo-Productivist' Agriculture." For the introduction to a related concept of *sustainable intensification* see Rockström et al., "Sustainable Intensification of Agriculture."

in a variety of bio-geo-chemical processes that make life on the planet possible.[5] This in turn has opened up the debate about the public impacts from the management of soils as private property and the needed changes to the soil governance. As a result, the negative environmental impacts of current forms of soil management practices have come under scrutiny, and been identified as the causes of large-scale disturbances in hydrological, carbon, and nutrient cycles. These practices include ploughing of the soil, changes in land use from pasture to arable (ploughing up grasslands), draining of wetlands, simplified crop rotations, and other practices associated with the intensification and extensification of modern agriculture, as discussed further below.[6] Changing these practices so that labor as a process of making soils into resources for capitalist agriculture is carried out by soil biota rather than human farmers with tractors and chemicals is seen to offer a way to maintain and even enhance agricultural production while improving soils and wider ecosystems. This convergence of interests is giving rise to a curiously nonadversarial dialogue between environmentalist and productivist objectives in relation to soils.

This conversation is, importantly, informed by the growing recognition of soils' capacities as living and lively ecosystems.[7] Soil is both inhabited and formed by a variety of still largely unknown biota, including bacteria, archaea, and fungi as well as the meso- and macroorganisms such as soil animals, and the plant and animal life with whom they form complex relations. The *Global Soil Biodiversity Atlas,* the first ever publication to chart the global status of soil organisms, states simply that "the role that living organisms play in soil development cannot be overstressed. The accumulation and decay of organic matter, the development of soil structure, the mixing of soil material (bioturbation), nutrient cycling, the physical breakup of bedrock by roots and the bacterial destruction of clay minerals are all the result of organisms living in the soil, and are critical soil-forming processes."[8]

This foundational liveliness of soils is producing hypes and hopes centered on the possibilities of remaking agriculture through new configurations of soil labor. New soil management practices are being called for that would better respond to and/or harness soils' liveliness. For some, laboring soil biota are promising a more productive management of soils as private assets. An important focal point here is soil organic carbon, whose higher concentrations correlate positively with higher yields in crops such as wheat, maize, and rice.[9] Methods of land management that can contribute to the

5. Hartemink discusses the changing definitions of and understandings of soils in "The Definitions of Soil since the Early 1800s."

6. See, for example, Food and Agriculture Organization of the United Nations, "Status of the World's Soil Resources," and Stockdale and Watson, "Managing Soil Biota."

7. For the importance of liveliness of certain entities to capital accumulation see Haraway, *When Species Meet*.

8. Orgiazzi, Bardgett, and Barrios, *Global Soil Biodiversity Atlas*, 25.

9. Lal, "Enhancing Crop Yields in the Developing Countries."

creation of soil organic carbon, such as no-plough farming and the use of cover crops, can also "create expanded habitat and greater niche diversity for soil biological communities," which in turn build said soil organic carbon by breaking down organic matter.[10] Such methods, then, are widely discussed as potentially enhancing both soil ecologies and yields. While changing land management is one way of enrolling soil biota into improving productivity, more direct ways of intervening in and reshaping the soil microbiome in the interests of agriculture are opening up through the use of genetic analysis and modification technologies. The emerging knowledge of soil microbiome ecologies is being linked with efforts to engineer soil microbiomes through various mechanisms so as to enhance specific microbiome functions, notably those related with crop performance.[11] In this, agro-sciences are casting soil organisms in the role of agricultural laborers as well as seeing in their genetic code new forms of exploitable biocapital.[12]

Those concerned with limiting the environmental degradation caused by modern farming embrace soil biota as ecological actors, hoping that replacing mechanical and chemical labor with the work of soil organisms may produce positive environmental outcomes. Drawing on the practices of permaculture, Puig del la Bellacasa expresses hopes that the need to respect soil biota's natural life cycles to achieve soil health may lead to a revision of productivist temporalities.[13] Having studied practitioners of Zero Budget Natural Farming in India, Münster and Poerting suggest that an engagement with soil biota has the potential to move farming away from the dominant ontology of land as resource, in which land is predominantly cast as a measurable, tradable, transferable entity and toward the ontology of land as soil based on an engagement with land as concrete, tangible, and living.[14] Similarly to Puig de la Bellacasa they suggest that working with soil biota demands care and attention that cannot be achieved through productivist approaches and progress-oriented timescales, thus producing spaces for more hopeful agro-ecological futures. In both narratives, changing the way humans work (with) soils through a greater enrolment of soil biota is seen as a path for a successful overcoming of the rift between social and natural worlds that continues to characterize modern modes of food-getting.

In this article, I examine this changing nature of the processes of soil-related agricultural labor drawing on ethnographic fieldwork with English farmers practicing

10. Lehman et al., "Understanding and Enhancing Soil Biological Health," 992; see also Stockdale and Watson, "Managing Soil Biota."

11. See, e.g., Chaparro et al., "Manipulating the Soil Microbiome," and Mueller and Sachs, "Engineering Microbiomes."

12. Granjou and Philips discuss such emerging discourses of soil labor among French scientists in "Living and Labouring Soils."

13. Puig de la Bellacasa, "Making Time for Soil."

14. Münster and Poerting, "Land as Resource, Soil, and Landscape." Please note the original article by Münster and Poerting is in German; the citations are this author's translations.

sustainable land management. In dialogue with their perceptions of and experiences with the changing nature of soil labor, I argue that enrolling soil biota as laborers is currently reinforcing rather than transforming the status quo of agrarian productivism. I suggest that changing the mode of agricultural labor from tractors and chemicals to soil biota is consistent with the pre-existing "improvement" drive of capitalist agriculture. As they reproduce and indeed intensify the ways through which soils can be made into economic resources, practices of enrolling soil biota as laborers are likely to reproduce and may reinforce the existing dynamics of domination and exploitation of environments.

This article makes two main interventions. Firstly, it contributes to debates about the participation of nonhuman nature in capital accumulation. To date, in this literature the processes of making nature into resources, and the processes of nonhuman labor, have been considered separately. This has to do with the historical separation of labor and nature in Marxist theory of value. I argue that we can instead productively collapse this distinction, and see labor as a material process of transformation oriented toward the generation of capital value. We can then, first, treat labor as not an exclusive property of humans, and second, see it as inherent to processes of resource making. Acknowledging the co-constitution of (any form of) labor allows us to better analyze the processes through which natures are rolled into capital.

Secondly, I ask what the enduring significance of labor as the primary mode of relating to soils in agrarian modernity means for our understanding of the disruptive potential of lively soils. Unlike the big-like-us, microorganisms such as soil biota challenge the separation between living and nonliving, *bios* and environmental services. Their bio-geo-chemical agencies have world-making consequences we are struggling to conceive of; their systemic nature confounds us. This situation challenges us to think carefully about what futures enrolling soil biota into labor framings and practices may produce for the landscapes in which we dwell, as we have little understanding of the material capacities of soil biota as laborers for capital. I also suggest that if we treat soil biota as soil laborers, we are likely to reproduce the same processes of alienation and exploitation that characterize the relations between capital and human labor.

I draw on ethnographic data collected at twenty-two conventional (not organic) farms in England between 2016 and 2018 (ten arable, nine mixed, and three livestock). The participants were all farmers who self-identified as practicing some form of sustainable land management. I interviewed farmers across a variety of soil types and agro-ecologies, undertaking different forms of sustainable soil management and with a wide range of length of experience with these methods. I conducted initial one-hour telephone interviews to establish basic information about farm size, machinery used, crop rotations, and the farmer's history on that farm. I also began to explore the farmer's interest in, perceptions of, and practices related to soils and their liveliness. This information was then further built on during farm visits, which lasted between two and four hours. During farm visits I combined semi-structured and unstructured

interview techniques to engage with the diversity of ways the farmers were relating to their soils.[15] The interviews combined a focus on life-story narratives (e.g., of soil management change) and on specific practices of soil-related work and assessment. To engage with the latter, the visits involved a combination of viewing and discussion of farming machinery as well as of records of soil analysis and soil maps, on-site interviews about particular fields, and, if practiced, observation of farmers' soil assessment. This usually involved the farmers digging shallow soil pits while being asked to narrate their perceptions of the soil's qualities and processes. It is in the context of these walking and digging interviews that the relationship between soils' liveliness and the changing nature of the farmers' labor was most discussed.

Making Nature into a Resource: Soils as Private Assets and Public Goods

We are just getting started with the interview when I ask Richard what role the soil plays in his farming system, and he asks me if I had heard of the apple analogy. I haven't, and he brings an apple and a knife over to the table, cuts into the fruit, and starts explaining.

> You cut the apple into four pieces and throw away three pieces and keep a quarter of it. So if that apple is your world that's your land. And then you cut it in half again and that's the ice caps and the desserts, and then you cut it in half again and that's your forests, and then you cut it again and you got the rocky areas, and then you cut it in half again and it's all the cities and the built up areas, and you're left with 3 percent. So that's what we've got to grow the food on. And then you peel the peeling off—because it's only the top that's where our food comes from. And that's what we're looking after on farms. That's the challenge we face.[16]

We laugh at the tiny sliver of nothing that is supposed to represent the world's arable soils—the food-producing resource. This framing of soil as a (endangered, precious, nonrenewable) resource, and the primary asset of a farm, has become so widespread as to appear common sense. However, much academic work has undermined such seeming "naturalness" of resources. This literature makes apparent the weirdness of perceiving of agrarian soils as somehow separate from their socio-ecologies; as a sliver independent from the rest of the apple.

In human geography, anthropology, political ecology, and political economy, scholars have examined the processes that make it possible to translate an element of the

15. Some of the themes explored in phone and face-to-face interviews included: the farmers' knowledge of and perceptions of their soils and their qualities; the farmers' experiences of soil-related challenges, and methods for addressing them; and the farmers' experiences with and motivations for undertaking different soil management methods.

16. This analogy was originally developed by the American Farmland Foundation (www.youtube.com/watch?v=_J9cg7dxD5E; accessed December 8, 2018).

natural world into an economic resource, exploitable by capital. This literature often stresses the external processes that drive the resourcing of natures, suggesting resource making is a locally materialized outcome of (frequently contested) nonlocal processes of expert knowledge generation, market development, valuation, and governance.[17] The weirdness and violence this imposition of such capital-markets-driven external frameworks on local socio-ecologies was notably discussed in Polanyi's *Great Transformation* in relation to the market valuation of land. As he showed, the sixteenth-century privatization and enclosure of commons land in England, and the forced removal of local populations from said land, constituted a dramatic and unprecedented act of separation between human habitation, social reproduction, and the natural environment. Importantly, the driver of enclosures was the pursuit of improvement—the landowners' desire to enhance the productivity of their soils in the pursuit of profit, an ambition that itself can only be understood in relation to the emergence of free capital markets. Land is not only of the environment but also is the environment. As Polanyi notes, "The economic function is but one of many vital functions of land. [Land] invests man's life of stability; it is the side of his habitation; it is a condition of his physical safety; it is the landscape and the seasons.."[18] Through land enclosures, these socio-ecological functions of soils were cleaved from the functions soils play as an asset for capital accumulation. At the same time, land labor was cleaved from the reproduction of dwelt landscapes, and became linked with the reproduction of capital. This double cleaving is the source of the ongoing tension between land and land labor as a source of market value (a private asset), and land and land labor as a reproduction of a socio-ecological environments (a public good). This is the tension which, for some, the turn to soil biota in agriculture is promising to breach.

While foundational, Polanyi's exclusive focus on governmentality and markets may lead us to focus on external processes as primary in the transformation of nature into economic resources. This dominant focus on purified human agency in resource making has been critiqued by Richardson and Weszkalnys, who argued that the making of resources needs to be seen as a material process in which the resource extractors/managers, the socio-material assemblages they form part of, and the resources they pursue come into being together.[19] Thinking soils through a resource materialities approach injects both a spatial and a temporal dynamism into what may otherwise appear as placeless and linear (even predetermined) and decidedly human processes. It uncovers the unstable, dynamic, and contested nature of the resourcefulness of resources as well as toward the everyday dimension of resourcing as a localized and hybrid activity. The specific properties of resources, "their dispersion, finitude, or renewability—are the outcomes of momentary stabilizations and continuous shifts in assemblages of

17. This approach is shared by Hudson, *Producing Places*; Mitchell, *Carbon Democracy*; Barry, *Material Politics*; Li, "What Is Land?"; Kama, "Contending Geo-Logics"; and Weszkalnys, "A Doubtful Hope."

18. Polanyi, *The Great Transformation*, 178.

19. See Richardson and Weszkalnys, "Introduction."

humans and nonhumans."[20] This relational resource materialities approach thus shifts the balance from linear human intentionality bent on creating value out of nature toward resources as becoming and emergent valued nature. It also stresses the contingent, dynamic, and ongoing activity of value creation involved in making nature into a resource.

This relational materiality dimension is crucial in understanding the resourcing of agrarian or otherwise cultivated soils. What matters about agrarian soils to humans is not so much what they are, but what they can do. Their external valuation through markets and expert appraisal only indicates soils' potentiality for economic productivity, their resource potential. Unlike gold or coal, soil cannot be extracted: "Land is not like a mat. You cannot roll it up and take it away."[21] The value of a soil as an economic resource therefore is not achieved through its commodification but through ongoing mobilization of its productivity—its capacity to support plant life that in turn becomes commodified. In the capitalist agrarian context, the value of soils lies then not so much in their static and unchanging properties but in their affordances; not in their materiality but in their relational materiality—in what they can do for the landowners, in relation to the landowners' objectives (which indeed are coproduced with the relational materiality of soils). The resourcing of agrarian soils, then, must be understood as a dynamic and ongoing process of assembling and mobilizing human and nonhuman elements of the world to produce capital value through plant productivity. The historically and geographically specific socio-ecologies of soils matter a great deal to this process. The status of soils as private property and the existence of free markets can be seen as the basic conditions for the transformation of soils into resources. However, these are not sufficient conditions. To become resourceful, soils also have to be mobilized through labor.

The Making of Fertile Soils

> "Cursed is the ground because of you;
> in toil you shall eat of it all the days of your life . . . ;
> By the sweat of your face you shall eat bread."
> —Genesis 3:17, 18

When I visit Shawn, we walk his fields and chat about the history of his land. There is a smell of sea in the air, and seagulls are circling nearby. The land his farm stands on used to be tidal marshland regularly flooded by seawater. He tells me the building up of sea defenses started around two hundred years ago, but the land was only brought into agricultural production after World War II. "The ministry of agriculture sort of came out to try and reclaim the land and convert it," he tells me. "It was all just leveled out

20. Richardson and Weszkalnys, "Introduction," 22.
21. Li, "What Is Land?," 598.

with bulldozers, so quite a high percentage of my farm doesn't actually have any natural topsoil. . . . So what it means is that really I'm starting from scratch as far as topsoil, and building organic matter . . . and I used to plough and cultivate it and try and make a seed bed with this sort of, just pure clay really, never very successful." It was the frustration with an endless "creeping up and down the fields" in a tractor that made Shawn consider farming his land without tilling it. This today allows him to grow a crop while building up the topsoil his clayey fields so desperately need.

This short vignette illustrates the importance of labor, understood as a material process of transformation under the capitalist mode of production, in the making of resource materialities. A number of studies have examined the importance of such processes as investment, governance, expert appraisal, and promissory narratives in the assembling of resources as relational materialities.[22] Perhaps due to the primary focus on resource extraction, and therefore on the turning of raw resources into commodities, this literature has attended less to the importance of labor as an *ongoing process of material transformation* in achieving resource materialities. The studies that do consider the interplay between labor and relational materiality in the making of resources have focused on the interplay between resource materialities and labor relations, examining the material world as involved in the shaping of human labor relations and their political capacities.[23]

The labor involved in the processes of resource making is oriented toward the achievement of specific resource materialities; the object of labor is to achieve specific relational qualities. The quality which matters most in relation to agrarian soils is fertility: soils' capacity to grow and sustain abundant plant life. Soils are composed of minerals (silt, clay, and sand), water, air, and organic matter as well as living organisms from the micro to the macro scale. A soil's natural fertility derives from interactions between these biotic and abiotic components as well as the soil's geographical situation (topography and climate). Human populations impact these pre-existent soil properties in significant ways; however, soil sciences have been resistant to the incorporation of human activity as a factor in soil formation (see also Meulamans, in this issue), with significant consequences for social sciences approaches that draw on natural scientific understandings of soil dynamics.[24] While the study of the negative impacts of human activity on soils, such as soil degradation, has produced a voluminous literature in both social and natural sciences, in contrast the human contribution to soil productivity

22. On the role of investment, see Li, "What Is Land?," and Le Billon and Sommerville, "Landing Capital." On the role of governance, see Kama, "Circling the Economy" and "Contending Geo-Logics." On expert appraisal, see Mather, "From Cod to Shellfish and Back Again?" On promissory narratives, see Onneweer, "Rumours of Red Mercury," and Weszkalnys, "A Doubtful Hope."

23. Mitchell, *Carbon Democracy*; Kaup, "Divergent Paths of Counter-Neoliberalization"; Rolston, "The Politics of Pits and the Materiality of Mine Labor."

24. Swidler, "The Social Production of Soil"; Engel-Di Mauro, *Ecology, Soils, and the Left*.

and fertility, particularly as a relational material achievement, has received much less attention.[25]

Fertility has predominantly been treated as a pre-existing, "natural" property of soils which is then brought into relations with human societies. Studies of the relationship between humans and agrarian soils have largely relied on static notions of soil fertility as a pre-existing property encountered, exploited, and often degraded by humans. Fertility, however, is a relational achievement; not something that occurs in soils, but an emergent property of human and nonhuman processes. This shifts our understanding of the objective of agrarian labor as the creation of *soil fertility* to the creation of *fertile soils*. A handful of studies in ethnopedology, which studies local soil knowledge systems and land use practices, have begun to articulate a similar approach. While still depending on the nature/culture dyad in their analysis, nonetheless these studies reconceptualize soil fertility as a dynamic process of co-evolution between soils and humans. Challenging the long-standing reliance on natural soil fertility to explain relations between soils and indigenous agrarian societies, WinklerPrins and Sandor note that while some soil properties that inform fertility (for example soils' mineral composition) remain beyond human intervention, these are not "so constraining as to eliminate human creativity and ingenuity."[26] Similarly, although not couched in this language, one could read Fairhead and Scoones's discussion of traditional African agrarian practices as distributed achievements of fertility, in which productive soils emerge from an assembling of, for example, work, investment, irrigation water, and proper household relations.[27]

A further step in this creation of fertile soils as a relational achievement is to link soil fertility with the capitalist mode of production. In capitalist farming, soil fertility is conceptualized in a particular way, as Lyon's account of soil fertility controversies in Columbia illustrates.[28] As she notes, the soils of the Amazonian plain are judged to have low fertility in relation to conventional modern farming methods and crop varieties, and are seen to demand numerous corrective measures, including heavy fertilization. The same soils, however, are seen as highly fertile when instead of conventional monocultures farmers cultivate plants as part of the wider forest ecosystem. The capacity of the same soils to support plant life, to be resilient, and to feed human bodies, differs in relation to the configuration of the farming process, and in relation to the expectations around the character and amount of biomass produced. This processual view of soil fertility also requires us to be attentive to the objectives guiding the assembling of human and nonhuman activities in the making of soil into particular kinds of resources—particular kinds of fertile soil.

25. The exploration of land degradation as socio-ecological by Blaikie and Brookfield in *Land Degradation and Society* lay the foundation for political ecology.

26. WinklerPrins and Sandor, "Local Soil Knowledge."

27. Fairhead and Scoones, "Local Knowledge and the Social Shaping of Soil Investments."

28. Lyons, "Soil Science, Development, and the 'Elusive Nature' of Colombia's Amazonian Plains."

Making Soils a Resource: The Labor of Improvement

Talking with Shawn and other farmers whose land had only recently become fertile soils under capitalist agriculture drew my attention to the importance of labor in transforming the "green and pleasant land" of England into the specialized productivist agrarian landscape of today. Central to these processes has been the concept of improvement, the objective of which was to make land more productive through changes to how soil labor was performed. In the pursuit of soil improvement, both the character of land, and the character of land labor, were transformed. Since land enclosures in the sixteenth century, agriculture had been both extensifying and intensifying processes of land labor.[29] Firstly, progressively more land was made available to labor, as new arable land was created through the draining of marshland, ploughing up of moorlands, grubbing up of woods, and even reclamation of land from the sea.[30] Secondly, the nature of the labor was transformed through new farming techniques and technologies. As one commentator noted in the 1980s, thanks to the changes to agricultural labor through tractors and chemicals, while "the inherent quality of the land does determine the pattern of agriculture . . . where climate, slope and altitude are not unfavorable it has been possible to change the prevailing regime quite successfully."[31]

The narrative of improvement reproduces Marxist understandings of the creation of value as a dynamic interaction between labor and nature. For Marx, capital value is created when nature and labor are brought together in a productive metabolism.[32] Marx understood labor as "a process between man and nature, a process by which man, through his own actions, mediates, regulates and controls the metabolism between himself and nature."[33] This understanding of value creation through the coming together of labor and nature (the labor theory of value) sets up an important dichotomy. Labor, although emergent from socio-ecological relations, is nonetheless seen as a uniquely human capacity to transform the material world. The character and organization of the labor processes change constantly so as to enhance the efficiency and productivity of these material transformations, and thus enable greater capital accumulation. In contrast to the dynamic nature of labor, nature is seen as presenting obstacles to the accumulation of capital, especially in its dealing with natural resources. In agricultural production, Goodman et al. argued, nature poses limits to capital accumulation due to the unalterable temporal and spatial properties of organic growth of plants and animals.[34] As a result, in capitalist agriculture, the objective of human labor is to optimize the environmental conditions in which these relatively intractable organic

29. A full analysis of the complex socio-ecological history of English agriculture is beyond the scope of this article, but I recommend Duncan, *Centrality of Agriculture*.

30. Burchardt, *Paradise lost*.

31. Holderness, *British Agriculture since 1945*, 46.

32. Robertson and Wainwright, "The Value of Nature to the State."

33. Marx cited in Robertson and Wainwright, "The Value of Nature to the State," 895.

34. Goodman, Sorj, and Wilkinson, "From Farming to Biotechnology."

processes occur.[35] In this labor-nature dyad, labor is the one that is seen as the more malleable.

Others have noted, however, that increasingly the other side of the dyad, nature itself, is similarly being intervened into and re-structured so as to provide greater capital accumulation potential. Boyd et al. argued that in some circumstances, nature can be subsumed into capital, especially in the case of biologically based industries in which resources are cultivated rather than extracted.[36] Under what they call the real subsumption of nature, the nature of nature—the processes and properties of the natural resources themselves—are changed so as to enhance profit accumulation. By changing, for example, the character of nutrient flows in an ecosystem, or the genetic makeup of organisms, "Nature . . . is (re)made to *work harder, faster, and better*" (emphasis added)[37] There is an emerging literature looking at just such an extension of capital's power through a continuous improvement on nature through e.g. genetic modification, or modification of the microbiome. In this sense, then, nature is emerging as just as malleable to the improvement drive inherent in capital as labor.

Instead of conceptualizing such extension of capital into the nonhuman realm as a transformation of nature, we can, however, extend the sphere of labor to the nonhuman realm. There is a growing, and contentious, literature on nonhuman labor and its relation to capital production.[38] Extending the notion of labor to the nonhuman realm allows us to appreciate the importance of liveliness and inventiveness of nonhumans to the reproduction of capital; organisms' natural capacities are no longer the obstacle to, but the very engine of capital.[39] In the case of animals grown for food, for example, Beldo has argued that the animal's very existence can be understood as metabolic labor—the animal body is both the animal existence and the commodity, and the metabolic processes are therefore both labor and life.[40] The manipulation of these metabolic processes so that more value is produced changes both the bodies and lives of nonhumans, and their contribution to the generation of value. The case of soil biota's participation in the production of capital corresponds in some measure to Barua's concept of ecological labor.[41] He suggests, however, that in ecological labor "life/time can be, and remain, extrinsic to capital production."[42] This idea of the immunity of ecological labor to the transformative power of capital is troubled in the context of resource making if we see labor and resources as co-constitutive. In the case of soil biota, their metabolic and ecological lives are inherently linked to the resourcefulness of land as fertile soil.

35. Hudson, *Producing Places*, 298.

36. Boyd, Prudham, and Schurman. "Industrial Dynamics and the Problem of Nature."

37. Boyd, Prudham, and Schurman. "Industrial Dynamics and the Problem of Nature," 564; my emphasis.

38. For a thorough review see Barua, "Animating Capital."

39. A point made also by Moore in *Capitalism in the Web of Life*; though note that Moore does not discuss animal labor.

40. Beldo, "Metabolic Labor."

41. Barua, "Animating Capital."

42. Barua, "Animating Capital," 6.

As a result, these very lives become as open to direct and indirect manipulation in the name of capital accumulation through e.g. greater efficiency and productivity as the lives of broiler chickens or dairy cows. The objective is not the production of better soil biota commodities, but the production of better conditions for the commodification of crops through the metabolic-ecological work these soil biota undertake. The materiality of soil biota, combined with our current techno-scientific capacity to intervene in this materiality, means that at the moment such manipulation occurs at the level of ecosystems rather than at the level of individual bodies (e.g., cells). Nonetheless, such manipulation is both already underway and is an aspiration for farming and research communities.

From Mechanical to Biotic Soil Labor

> Let the soil do the work instead of working the soil.
> —Tweet, Conservation Agriculture Youth Association, November 8, 2018

Until recently, modifications to human labor were the predominant way for improving soils' resourcefulness. Soils are productive when plants have optimal access to nutrients, water, and air. As a result, in farming desirable soils are those which are nutrient-rich, moist but not waterlogged, and with a structure that does not obstruct the development of roots. Some soils offer some of these qualities some of the time. In most cases, farmers' labor is to change the material qualities of the soil so as to generate an optimal environment for the crops. The growth of tractor engine power and developments in farm equipment design make it possible today to work the soil with unprecedented intensity.[43] A short vignette from a soggy field illustrates the sheer scale of material transformation of soil this mechanical power enables. Andrew, the farm manager, and I shout to hear one another over the noise. A huge tractor on wide caterpillars is working behind us, dragging a subsoiler, a metal tine under the soil surface, breaking up a compacted soil layer. Andrew explains to me this and other machine work the field will undergo to prepare it for the next seeding:

> This soil has been in anaerobic conditions [due to compaction], it's going to need this subsoiling operation. . . . Then, we will probably have to spring tine cultivate . . . it's a series of tines which have sort of coiled springs at the top so they vibrate as they go across the ground, and if we can get those clods on top dry, that should shatter them as it passes through. And then following that we will probably have to what we call power harrow, it's a rotary machine, which passes quite slowly across the field . . . just creating the tilth on top. And then we'll drill [the seed] into that.

The intensity of the work Andrew describes—the number of times a tractor will travel up and down the field, the number of different tools used, the man-hours, energy

43. For a history of agricultural machinery in the UK see Dewey, *Iron Harvests of the Field*.

and materials used up in this process—is astounding. The objective of this immense effort is the material transformation of soil structure; the qualities of the soil are changed through this labor. This intense engagement, which is the norm in conventional land management, is beginning to be questioned by some farmers. The link between the heavier and heavier *working of* soils, and better and better yield outcomes, seems to be broken. These farmers identify a kind of negative intensification, in which a greater amount of mechanical work produces progressively worse outcomes. Daniel, who farms clayey land in the Vale of York ("stuff to line your ponds with," he laughs), told me he started to see his soils as overworked. A greater amount of his labor was not producing better yields.

> The areas that ten years ago may have needed one pass with a power harrow suddenly needed two [. . .] you were having to work them more and more and more to get the seed bed you would have got quite easily 10, 15 years ago. [. . .] And I believe that what I was doing wasn't helping, it was making it worse, over-cultivating.

In farmers' narratives, soils are often described through the embodied engagement of soil-work as heavy and light, forgiving, and "real man's land." The feelings of "struggling" with their soils to achieve desirable seed beds, of having to "beat the soil into submission," leads some to reflect on the nature of soil-related labor. Soil struggles have significant costs, both in terms of time and fuel. No-tillage crop establishment methods, in which the seed is drilled directly into undisturbed soil, presents an attractive possibility of achieving the same or similar outcomes in terms of yield with less capital outlay. As Edwin commented, explaining his shift away from ploughing, "We can throw as much machinery at our soils [as we like] and our output will not improve. We need to improve our soil to improve our output."

In addition to stopping ploughing, Edwin uses other conservation agriculture practices, including a diverse crop rotation and planting cover crops. In this approach to soil labor, the optimal crop environment is achieved not through direct manipulation of the soil through mechanical means, but indirectly, by mobilizing the capacities of soil biota. Soil organisms have the capacity to change soil structure from within, as part of their living and dying, of their moving about and staying put. Their bodies and metabolic activities create soil organic matter, which in turn changes the structural characteristics of soils. Removing tillage and introducing e.g. cover crops changes the orientation of farmers' labor in terms of soil structuring—from working the soil to working with the soil (biota). The change to agricultural labor is epitomized in the "roots not iron" slogan, used by farmers who call for the use of cover crops—plants sown between cash crop rotations—to harness the power of plant roots themselves, and to reinvigorate soil ecosystems and produce good seed beds without the need for ploughing.[44]

44. E.g., www.no-tillfarmer.com/articles/8221-why-roots-not-iron-are-key-to-a-more-prosperous-no-till-future.

Figure 1. RIP Plough, a statue shown during Groundswell in 2018. Groundswell is a farmers' conference for promoting no-tillage and other sustainable soil management methods. Photograph by Alex Cherry; used with permission.

Whereas concerns about soil structure lead to a replacing of the labor of the farmer with the activity of soil biota, soil organisms are also capable of going beyond what is possible for farmers to achieve. One of the soil microbiota's most attractive capacities for farmers is their ability to mobilize nutrients that are present in the soils, but inaccessible to crops. This is especially pertinent to micronutrients, whose deficiencies can be hard to remedy once the damage is done. Tim, a sheep farmer, told me about a time when his lambs started losing their ears during a dry, hot spell. The cause of this, he found, was extreme sunburn due to a cobalt deficiency. The animals were entirely grass fed, which meant the cobalt, while present in the soils, was not being taken up by the grasses in this dry period, and so was not available to the livestock. Before Tim and

his partner took the farm over, the land had been under intense arable cultivation, and had very low levels of organic matter. The various illnesses the flock was suffering from, they found, were ultimately linked with multiple micronutrient deficiencies, caused by the soils' inability to hold moisture. The pathway to a healthy herd was through building a healthy soil, rich in soil organic matter and biologically active. While providing the herd with nutritional supplements, the partners also begun to work on improving the soil itself by encouraging greater microbial activity. They employed a method called mob grazing, in which the herd is contained within a small area that is heavily grazed—and heavily fertilized with sheep excrement—and then left to re-grow. In addition, they spread compost and other organic matter, and used a variety of grass species, all to provide food to fuel a growth of soil biota. As Tim explained,

> My thought is once the soil biology is getting back and everything is more mobile in the soil and these minerals are more biologically available, that won't become so much of a problem. I think it [the soil] will naturally heal itself. . . . The less we can get ourselves involved with our human ingenuity the better things generally get. [We're] trying to facilitate nature to solve the problems for us, because it's almost too complicated for us to understand.

This redistribution of labor from farmers to soil organisms seemed, for Tim and others, a better way of managing the land. The capacities of soil biota exceeded his own; he could not keep up with the mineral deficiencies in his flock, but the soil biota could prevent those deficiencies from occurring in the first place. For Tim and others, the ideal soils were thus soils that "do it themselves" as it was often put—that farm themselves. An ideal, resourceful soil does not require the farmer to toil in it, but provides the crops with all the nutrition, water, and air access they need—for free, and much more efficiently than a farmer could. The labor process and its objectives are retained: the support of crop growth for profit production. However, the labor itself is performed by different bodies. While the labor of the farmers continues to be important, its character changes. The soil is not worked, but supported, fed, and "helped along." As Martin, a dairy farmer, explained, his objective was to

> Get that soil at a balance, so that it can do all the things that we want it to do. That we can get all the trace elements out of it, that it can look after itself, and also feed the crop or animal off it. . . . And if it gets compacted bounces back, repairs itself. That's my dream.

Improving Soils through the Labor of Soil Biota

In these soil-biota oriented farming methods, the labor of soil improvement is redistributed from the farmers to soil organisms. Farmers become soil managers, in that they oversee, facilitate, and attempt to shape the labor performed by soil biota so that

their objectives are achieved. In that process, some characteristics of the previous (human) soil labor are retained, while others are changed. Firstly, the farmers' other land-related practices become supported by the labor of soil biota. Through the labor of soil biota, the soils become more workable for the farmer. It becomes cheaper and quicker to carry out the necessary agricultural practices such as seeding and harvesting, leading to financial and time efficiencies and so potentially greater profits. Secondly, soil biota directly replace some aspects of farmers' soil labor. Whereas in "lifeless" soils the farmers' labor to create soil structure, in soil-biota-oriented systems these activities are performed by soil organisms. Thirdly, new resource frontiers within soils are opened through the agency of soil biota. Through their metabolic processes and products, soil organisms can mobilize locked-up nutrients, and retain water, creating a better environment for the growing crops. Microbial labor occurs at scales and temporalities inaccessible to the farmer; soil organisms are always already there, their labor of improvement is potentially ceaseless. Enrolling soil biota into agricultural labor thus produces a true working agrarian landscape—not being worked *by*, but working *for* the farmer.

This shift from working the soil to working *through* soil organisms can also result in positive environmental outcomes relevant to global and local ecologies. In producing soil organic matter, soil biota capture carbon from the atmosphere, and the scientific and policy communities are excited by this potential carbon sequestration mechanism.[45] Soils higher in organic matter can similarly prevent nutrient runoff, and can improve local hydrology.[46] However, for the farmers I interviewed, these outcomes were secondary to the promise of greater farm productivity that soil biota enable. While the lively soil may be described as more natural or healthier, the activity of soil biota that produces these outcomes continues to be valued through its link to the resourcefulness of soils. As a result, the changes to the agricultural labor that a care for soil biota demands must fit into the existing farm system, and align with its objectives. As Charles, an arable farmer using conservation agriculture methods, explained,

> When other farmers come and visit us, you know I try to stress to them you know, think of the cost-savings as an advantage, what you're really trying to do is create a better soil, a healthier soil which will grow healthier plants which will give you bigger margins, bigger outputs and therefore bigger margins basically. You know, I'm trying to grow better yields than I ever have done not just an acceptable yield at a low cost.

The activities are being carried out by soil biota; however, the objective remains the same: an improvement of soil for the benefit of the (monocultural, industrially farmed, commodifiable) crop. Replacing human labor enhanced by tractors and chemicals with the labor of soil biota, however, changes the spatialities and temporalities of

45. See, e.g., Food and Agriculture Organization of the United Nations, *Status of the World's Soil Resources*.
46. Stockdale and Watson, "Managing Soil Biota."

the resourcing of soils. Whereas previously the object of soil improvement was the *creation of an environment* for the crops within the fields, through the capacities of soil biota the objective becomes the *management of the wider environment* so that optimal conditions within fields are produced. In this manner, soil biota as laborers become agents of the so-called ecological intensification: the process of mobilizing ecosystem service providers so that "production is maximized while environmental impacts are minimized through the decrease, but not necessarily exclusion, of anthropogenic inputs."[47]

By passing the labor of making fertile soils on to soil microbiota, it becomes possible to think of the whole biosphere as explicitly engaged in and harnessed toward particularly conceived production processes. All processes in which soil biota are involved become potential objects of improvement—of material transformation for the benefit of capitalist agriculture. Soil biota's metabolic-ecological labor capacities extend the frontiers of resource making beyond the field boundary to involve watersheds and atmospheres. Soil biota do not only become resources but also become agents of the processes of making resources understood as the transformation of nature into productive assets for capital accumulation.

Conclusions

Attending to soil biota is creating a new interest in the role of ecosystems, and particularly soil ecosystems, in agricultural production. Whereas the environmental turn of the 1980s-90s, especially in European farming policy, was rooted in concerns about pollution and degradation, and the consequent need for conservation, the current interest in ecosystem actors such as soil biota has a rather different flavor. Some hope that the emerging understandings of soils as living may result in shifts toward agro-ecological approaches, in which the temporalities, spatialities, and intensities of food-getting are informed by the well-being and health of more than only humans.[48] By analyzing the new conceptualizations and practices of soil liveliness as a form of nonhuman labor in conventional capitalist agriculture, this article suggests a more cautious conclusion.

The current soil-biota-oriented farming and research practices are consistent with the logic of improvement that had historically informed changes to land labor in England so as to more successfully transform land into an economic resource for capitalist agriculture. Transforming land labor from an activity carried out by farmers with tractors and chemicals to an activity carried out by soil biota under farmers' management is a new manifestation of the improvement logic. The emerging understandings and practices of laboring soil biota risk reifying the ontology of land as a resource, both reasserting and expanding the enrollment of ecosystems into capital accumulation. For all the positive ecological outcomes that encouraging soil microbiomes may have, if soil

47. See, e.g., Bommarco, Kleijn, and Potts, "Ecological Intensification," 230.

48. Puig de la Bellacasa, "Making Time for Soil"; Münster and Poerting, "Land as Resource, Soil, and Landscape"; Granjou and Philips, "Living and Labouring Soils."

biota become primarily a means of reproducing capital their bodies and ecologies will become open to processes of destructive exploitation inherent in capitalism.

In this article I suggest that to better understand the role that nonhumans play in economic processes, we need to move beyond the conceptualizations of labor as either the "fictitious commodity" of capital markets (as per Polanyi), or as a separate part of the labor-nature dyad of value generation (as per Marxist approaches). Approaching labor as a material process of transformation oriented toward the generation of capital value makes it possible to consider labor as not exclusively a human characteristic, and as always linked with the making of economic resources. Focusing on nonhuman labor as an element of resource making opens up a dialogue between literatures concerned with the creation of new forms of biovalue and those exploring the role of nonhumans in capital accumulation.[49] Placing (any) labor as inherent to the making of resources as simultaneously an economic and material process allows us to move beyond the conceptualizations of nature as an obstacle to capital accumulation, and to explore the roles of nonhumans in capitalist economies not only as commodities but also as producers. Capital is produced through the lives and bodies of nonhumans and not only in opposition or conflict with them.

Seeing nonhumans as laborers, some suggest, may offer opportunities for multispecies solidarity. Following feminist critiques of the undervaluation of reproductive labor under capitalism, Battistoni suggests that conceiving of the activities of nonhumans as work begs the question of rights and of just remuneration for work rendered.[50] Framing nonhumans as comrades, she argues, can be productive of forms of solidarity with nonhuman nature against the destructive forces of capital. The relationship between labor, soil improvement, and intensification explored in this article suggests a less revolutionary direction is emerging. The violence and struggle characteristic of labor relations under capitalism, where labor is always pushed toward greater efficiency and self-exploitation have been similarly observed in relation to the labor of big-like-us nonhuman animals.[51] Approaching soil biota as laborers may thus act to reproduce rather than oppose the exploitative nature of the capitalist mode of production, dependent as it is on the undervaluation and continual squeezing of laborers, be they human or nonhuman.[52] The focus on the soil biota's productive function I identify suggests a continuation of existing intensification logics.

Exploring labor as a not-only-human process of transformation so that economic resources are produced allows us to further consider the importance of labor's materiality. In seeing capitalism as unfolding through relations between the economic

49. Birch and Tyfield, "Theorizing the Bioeconomy"; Barua, "Nonhuman Labor, Encounter Value, Spectacular Accumulation."

50. Battistoni, "Bringing in the Work of Nature."

51. E.g. Wadiwel, "Chicken Harvesting Machine"; Beldo, "Metabolic Labor."

52. On the role of "free nature" in capitalism see Moore, *Capitalism in the Web of Life*.

and the ecological, the material capacities of the ecological matter. As Barua argues, this perspective renders "nonhuman potentials as eventful, and as components in the organization of economic activity in their own right. Equally, accounting for the productive force of the nonhuman denaturalizes nature and recognizes its already-economic status as also-political."[53] The capacities of soil biota as workers at scales and temporalities inaccessible to direct human agency may enable the expansion of capital into new resource frontiers, both toward the macro, such as the bio-geo-chemical cycles within which food-getting is situated, and the micro, the configurations of soil microbiomes. Such research is already underway.[54] While the labor of intensification may be carried through the bodies of microorganisms rather than bodies of farmers, this should not lead us to conclude that necessarily a more agro-ecological or otherwise Gaian agrarian future is being brought forward.

The capacities of soil biota are diverse, powerful, and largely unknown. With new research, and the emergence of high-tech as well as low-tech practices for interacting with and changing soil microbiomes, soil biota are being invested with hopes of healing degraded lands, halting anthropogenic climate change, degrading plastics, enhancing yields, and many others.[55] In this, soil biota are becoming agents of human-directed *improvement of nature* far beyond food production processes. Understanding the capacities of soil biota as a form of labor, and acknowledging the co-constitution of labor and resource making, uncovers the logic of capitalist exploitation which underpins these processes of soil microbe enrollment. Through the labor of soil biota, more than just fields can be made into resources. Nature's real subsumption into processes of capital is extended from pure production to encompass the underpinning ecologies which make production possible in the first place.[56] The natural world is not just commodified, but reorganized in the service of capital accumulation. Transforming ecologies so that current dynamics of capital reproduction can be upheld and even intensified "invokes the logic of subsumption on a planetary scale."[57] As this transformation of the planetary into a resource unfolds, we will do well to remain mindful about the material capacities of soil biota as powerful and unknown agents of planetary change. Soils are the heart of the Critical Zone that makes life on our planet possible. Every time we change soils, we change everything else.[58]

53. Barua, "Animating Capital," 15.

54. As noted by Granjou and Philips, in the case of French agronomic research, in "Living and Labouring Soils."

55. See, e.g., the popular Montgomery, *Growing a Revolution*; and for a repository of news and research stories of soil biota hype see the newsletter section of the Soil Care Network (soilcarenetwork.com).

56. I discuss this further elsewhere as a form of probiotic environmental governance, which "retain the anthropocentrism of modernity while abandoning its pretense of sharp separations between categories, acknowledging the need for care for nonhuman agencies as relevant to human well-being." Krzywoszynska, "Caring for Soil Life in the Anthropocene," 6.

57. Carton, Jönsson, and Bustos, "Revisiting the 'Subsumption of Nature,'" 792.

58. On soils as socio-ecologically relational in the Critical Zone, see Krzywoszynska, Banwart, and Blacker, "To Know, to Dwell, to Care."

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