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Bringing soils to life in the human and social sciences

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ABSTRACT

Despite their key importance for ecosystems and societies, soils have long remained a peripheral topic in the human and social sciences. Our paper aims to account for the recent, fast-growing literature in human and social sciences on soils. We first highlight social sciences' shared concern for unsettling common visions of soil as a surface, a background or a taken for granted stock of resources; then we show that the works at stake differ in terms of: (i) their linkage with soil science disciplines and fields, (ii) the social science theories they mobilise, (iii) their main contributions, and (iv) their approach to soil materialities and agencies. Following these criteria, we present three strands of research on soil-related issues: (1) Literature bearing on the politics of soil knowledge investigates how soil becomes an object of knowledge and management; (2) Soil new materialism addresses practices and ethics of caring for the living soil; (3) Soil decolonial studies unravel soils' powers and the intertwined agencies of soils and societies. By examining these research agendas, we suggest that social and human thinkers have, in the past two decades, tended to shift from a focus on the socially constructed nature of soils, to a growing emphasis on soils' own biophysical agency in shaping societies, also in line with soil sciences insights and works. We argue that the increasing uptake of soil in human and social sciences contributes to an increasing concern for achieving better theoretical and empirical accounts of the co-constitution of society and the material world.

1. Introduction

Despite their key importance for ecosystems and societies, soils have long remained a peripheral topic in the human and social sciences. As Swidler (2009) argued over a decade ago, during the biggest part of the 20th century, canonical view of soil in the human and social sciences were often based on a possibilist model whereby soils were seen as a mere resource for the development of human societies. These views rarely aligned with soil sciences views about the dynamic nature of soils and their morphology, but rather with the relatively static agronomical and physicochemical approaches that dominated the second half of the twentieth century. During this period, according to Winiwarter (2014), agronomy broadcasted a limited conception of soil fertility based on a few agronomic factors, and tended to reduce it to a simple substrate able to absorb the nutrients necessary for the growth of cultivated plants. Despite notable breakthroughs inspired by pedology and soil mapping – such as the unpacking of various indigenous soil classification systems by ethno-pedologists (Barrera-Bassols and Zinck, 2003), or the study of the social causes of erosion by political ecology (Blaikie, 1985) – the majority of social and human scientists continued to see soil as a natural variable, a stock of resources, and a simple material basis for the social dynamics that play out on its surface.

Soil scientists, on their part, have long contemplated how human activities could be taken into account in their own discipline. Even though Hans Jenny's original formulation of the five factors of soil formation (1941) did not directly include humans, Jenny insisted that humans have the ability to modify and alter these factors. He later stated that humans were in fact a subset of the 'organism' factor (Amundson and Jenny, 1991), a rather naturalizing view of human activities. Others later considered that humans should be thought of as a separate anthropic factor (Effland and Pouyat, 1997) or 'sixth factor' of soil formation (Dudal, 2004). Towards the end of the century, these discussions gained importance as the scale of human modification of the earth's soils became more apparent. Lehmann and Stahr (2007) prompted the soil sciences to better develop a basic understanding of the functioning of anthropogenic soils, while Richter et al. (2011) insisted that pedology should altogether redefine itself as 'anthropedology,' a proposed disciplinary development that understands human activities as integral to

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soil genesis. In 2006, the new soil group *Technosol* made its appearance in the FAO's World Reference Base for Soil Resources (WRB), referring to soils and ground types that have been formed or heavily modified by human activities. Even though these attempts have attracted some criticisms because of the somewhat generic understanding of humans and techniques that they encompass (Engel-Di Mauro, 2014) based on de-historicised, de-contextualised, and de-politicized concepts of 'anthropos' and 'techne', they have helped develop a better mutual understanding between very separate disciplines. The attention towards anthropogenic soils has raised difficult questions about how humans' and other animals' actions differ, how technique comes to bear its mark on the environment to the point that it becomes hard to differentiate the two, and how to live on a planet that has become durably degraded.

Interestingly, these questions are also at the core of new approaches to soils in the humanities and social sciences that we address here. In contrast with earlier static approaches to soil, we have been witnessing an ecological turn of the soil sciences since the turn of the 21st century, relying on a (re)affirmation of the 'living' nature of soil and bolstered by a new interest in the microbial life that inhabits and creates it. The notion of 'living soils' (Gobat et al., 2004) – although not exactly a new idea (Balfour, 1943; Pessis, 2020) – has progressively gained new traction in the fields of pedology, ecology, decontamination and agronomy as well as in national and international institutions, opening up awareness to the role of microbiota within the functioning of the biosphere, as well as a 'downward' extension of the scope of inventorying and conservation concerns around soil meso- and micro-biodiversity. Soil, now described as the 'last biotic frontier' (André et al., 1994), is increasingly viewed as the earth's largest reservoir of biodiversity, with one gram of soil harbouring up to one million different organisms (Bardgett & van der Putten, 2014), most of which are yet to be described or even identified.

These new views also paralleled unprecedented attention to soils in the global environmental agenda (Hartemink, 2008; Hartemink and McBratney, 2008), as evidenced by the revision of the World Soil Charter and the launch in 2015 of the International Decade of Soils, and by the recent publication, alongside reports on global desertification (UNCCD, 2014), of reports examining the link between soil degradation and issues pertaining to biodiversity loss (IPBES, 2019) and climate change (IPCC, 2019), that all stress the rapid degradation of soils at the global level. These reports warn that nearly 33 percent of the world's soils have been irretrievably degraded by human activity (FAO & ITPS, 2015), that 24 billion tonnes of fertile soil is lost each year (UNCCD, 2014), and that soil in agricultural zones is lost 10 to 40 times faster than it is in natural soil formation and replenishment processes (Pimentel and Burgess, 2013). They stress that beyond concerns about threats to soil biodiversity, knowledge of soils is becoming ever more vital to the identification, management and securing of a wide range of 'services' (Robertson, 2012; Mc Bratney et al., 2014; Baveye et al., 2016) provided by soils, including food provision, waste decomposition, water filtration, climate regulation. This rise of soils as a topic in global environmental agendas and programs was also fostered by the rise of more holistic approaches in soil research, leading to the merging of traditional soil and agronomy programs into more environmentally related departments at the level of university training, and to new linkages and partnerships between pedology, agronomy and related sciences (geomorphology, climate science, etc.).

This suggests how the soil sciences have moved from an agronomic model of the soil as a 'stock' – a fertile capital subject to human appropriation – to a more ecological model approaching the soil as a dynamic and vulnerable ecosystem continuously produced by the activity of a myriad of organisms that populate it and degrade, transform and combine the materials that constitute it (Lavelle and Spain, 2001; Gobat et al., 2004; see also Churchman, 2010 for more details on the holistic focus on soil that has long been specific to soil sciences beyond the diversity of their sub-disciplines). In this review article, we assess how these new perspectives on soils as an animated compound, located in the physical and life sciences, offer possibilities for new articulations and understandings of soil-human relations in the human and social sciences.

We show that, paralleling the ecological turn in soil sciences and the rising focus on dynamic, living soils, recent literature demonstrates the emergence of a variety of new strands of research and thinking in the human and social sciences related to soils, that share a key concern for unsettling common visions of soil as a surface, a background or a pre-existing, taken for granted stock of resources for human enhancement and cultivation, and provide distinct understandings of soil activity and agency. By focusing on new objects such as public soil policies (Howard and Lawson, 2015), urban soils (Meulemans, 2020b), urban gardening (Mcclintock, 2010), the greening of tillage in agriculture (Krzywoszynska, 2019), relationships to soil microfauna in alternative agriculture (Birnbaum and Fox, 2014), or the use of soil as a convenient receptacle for a variety of wastes (Hird and Clark, 2013), these works take note of new approaches to 'living soil' (as unfolding in the natural sciences) and suggest to 'think with soil from the social sciences' (Salazar et al., 2020). They call for new approaches to soil, in the dual sense of territory and living substance, that would be able to take the measure of the fundamental importance and vulnerability of underground life forms. Our key point is that this developing literature does not only address the variety of people's engagements with soils and the socially constructed nature of soils: it also highlights the embeddedness of social and political patterns within soil shifting ecologies and biophysical dynamics, thus putting a growing emphasis on the importance of soils' own biophysical agency in building and shaping societies. This tendency thus tends to give more room for the consideration of the nature, functioning and evolution of soils within the human and social sciences works and literature, as they increasingly recognize that soils are not just as a mere stock, or a set of inert resources for human use and exploitation, but are instead active, dynamic and vulnerable ecosystems.

Rather than providing an all-encompassing review of this literature, this paper is intended as a reflexive report and discussion of the fast-growing literature addressing soils in the human and social sciences in the last two decades. Starting from the observation that these works are broadly located in Human Geography (see Table 1), but differ in terms of (i) their linkage with certain soil science disciplines and fields, (ii) the social science fields and theories they mobilise, (iii) their main contributions, and (iv) their approach to soil materialities and agencies, we identify and present three strands of social research on soil-related issues:

(i) The first set addresses the politics of soil knowledge, i.e. investigates how soil becomes an object of knowledge and management in various human groups and communities.
(ii) The second set addresses practices and ethics of caring for the living soil and documents the development of new relations and attunements with soil biota beyond productivist and technoscientific practices of soil fertilisation and control; this research calls for a better recognition of the agencies and vulnerability of the living soil.
(iii) The third set of literature offers decolonial approaches to soils, i.e. unravels soils' powers and the intertwined agencies of soils and societies; this research encompasses land and deep soils and stresses the role of soils in shaping not only the material basis for human life but also various political organisations and philosophical ideas across humankind development.

It should be noted that this typology does not correspond to well-bounded, successive periods: all three strands of scholarship have rather been coexisting during the last 20 years in an ongoing, still open conversation fostered by an increasing concern among authors to do justice to soils' materialities and agencies and their capacity to intervene, shape and reconfigure human communities and organisations. This conversation has led to the current coexistence of those three bodies

Table 1
Disciplines and fields in the human and social sciences.

Field and Discipline	Definition
Human geography	The field of geography interested in social relations to space and the environment.
Science and Technology Studies (STS)	A field of social sciences that investigates the practices, groups and institutions involved in the production, circulation and mobilisation of knowledge and technologies in society.
Social and cultural anthropology	Academic discipline that studies the development of human societies and cultures. Environmental anthropology is the branch of anthropology that studies human groups' relations to the environment.
Environmental history	A branch of history that addresses the joint transformation of human societies and natural environments and their interactions.
Political Ecology	A field in social sciences that addresses the political dimensions of environmental issues and problems, and accounts for the power relations and struggles at stake.
Continental Philosophy	a set of philosophical currents originating in continental Western Europe addressing topics such as the body, power dynamics, or consciousness, and relying on historical or textual analysis rather than formal logics.
Theories and approaches	**Definition**
Actor-Network Theory (ANT)	An approach in Science and Technology Studies that addresses technical innovation in terms of the development of a rising sociotechnical network i.e. a network involving both people and objects.
Decolonial theories	An approach, cutting across the humanities, that addresses the inequalities and relations of domination in North-South settings and denounces the enduring legacy of European-centric worldviews and colonial forms of imperialism in society.
Foucauldian approaches	Approaches, cutting across the humanities, inspired by Michel Foucault's focus on the role and history of knowledge discourses in the constitution of social realities and forms of state power.
Multispecies ethnography	An anthropological approach aiming to recognise the active role of non-human living beings in ethnographic accounts and unsettle the human-centred lens of anthropology.
New materialisms	A set of theories, primarily anchored in philosophy and anthropology, aiming to revisit the role of materialities in social sciences thinking. These theories of materialism are 'new' because they depart from the notion that the material world determines social and political dynamics (i.e. Marxist materialism) and focus instead on 'more-than-human' assemblages and communities where material and immaterial, or social and natural aspects of the world are intimately bounded.
Theories of Care	Writings that focus on activities and perspectives of caring for people and non-human entities and demonstrate their material and ethical importance.

of work that, each in its own manner, seeks to address not only how humans conceive of soils and transform them, but also how soils contribute to shaping human organisations and collectives. In particular, we would like to highlight social scientists' growing focus on accounting for the importance of soils' own biophysical dynamics and agencies in building and shaping societies. We argue that, in the past two decades, social and human thinkers have tended to shift from a focus on the socially constructed nature of soils, to an emphasis on the role of soils in shaping human organisations, collectives and philosophical ideas. Furthermore, this review suggests that the increasing uptake of soil in the human and social sciences should not be understood in terms of the emergence of a new 'discipline' or subfield dedicated to soil. Rather, it attends to human and social sciences' ongoing efforts and reflections to shape non-anthropocentric theories and epistemologies that would make it possible to rethink social existence no longer in terms of human-only categories and capacities, but in terms of the production of a 'more-than-human' world at the juncture of social and bio-geo-physical agencies.

In the rest of the paper, we shall describe those three sets of work and emphasise their tensions, mutual criticisms and attempts to better account for the co-constitution of soils and societies.

2. The politics of soil knowledge– how soil becomes an object of knowledge and management

A first set of literature, located in approaches ranging from Science and Technology Studies (STS), Actor Network Theory (Latour, 2005), Political Ecology (Leach and Mearns, 1996) and Foucauldian approaches to governmentality (Foucault, 2009) (see Table 1), addresses the way in which soils have been treated as a resource to be managed and exploited. Rather than taking soils as a taken for granted resource for exploitation, this research work aims to denaturalise the category of 'soil', by showing how the soil is constituted and secured as an object of knowledge, exploitation and government. These authors often posit that 'soils', as an entity, do not exist out there, ready to be surveyed and extracted as resources: instead the technologies of knowledge and prospecting (i.e. cartography, surveys, assessments and estimates…) contribute to them being *constructed* as intelligible and governable objects and resources. They stress that, to be governed, soils need to be rendered visible and calculable *via* a range of theories, devices and institutions. Several authors have therefore researched how soils are 'socially constructed' as knowable and manageable entities through expert and scientific categories. They often focus on conflicts and discrepancies in how soils are known, measured, and understood.

One strand of this literature draws on Actor Network Theory (ANT) (see Table 1) to show how qualifications of soils as 'resources' do not directly derive from their natural, taken for granted properties, but rather from discursive, legal and material mechanisms that allow them to be 'translated' or 'assembled' as such. For example, Murray Li (2014), an anthropologist working in the Indonesian highlands, uses an ANT approach to examine practices and devices that allow assembling formerly common land as a (private) resource open for global investment. In Li's account, devices such as fences, title deeds and regulations allow translating land and soil materially and discursively at the same time, changing how qualities and values are attributed to them, and making them participate in a very different form of social life organised around international trade rather than local dynamics. Accounts such as that of Li therefore describe how values and properties are attached to various soils, thus building the conditions for the exploitation of soil resources and their circulation on markets in the same movement.

Other authors taking a critical stance at modern, managerial approaches to soil have focused on conflicts and controversies between different ways of knowing and understanding soils – thus unpacking the 'politics of soil knowledge' meant as the various ways in which soils come to be known, represented, mapped, and conceived of by various soil practitioners, experts, and scientists (Kon Kam King et al., 2018). Farmers, foresters, government officials, soil scientists, or environmental NGOs know soils in different ways and attach different meanings to them (Warkentin, 2006; Landa and Feller, 2009). Moreover, the diversity of these understandings does not boil down to a simple division between scientific knowledge and local knowledge. Taking inspiration in Science and Technology studies scholarship, authors interested in the production, circulation and application of soil knowledge have shown how scientific and expert knowledge on soil is also situated in different social, disciplinary, institutional and economic contexts. Thus, a pedologist, an agronomist, or a remote sensing analyst differ in their understanding of soil dynamics, and in the scale on which they study them. For example, Kon Kam King and Granjou (2020) addressed the rise of soil digital mapping instruments since the turn of the 21st century and showed how these new techniques contributed to shifting soil science profiles and skills away from classical taxonomical pedological approaches toward making them part of Earth system modelling efforts; and how this contributed to recasting soil as a global container of carbon

to be measured, mapped and enhanced.

In a similar way, environmental historians have shown how, from the onset, the soil sciences have been riddled with controversies about how to define soil and to what end (Engel di Mauro, 2014). Furthermore, privileging certain kinds of soil understanding and sidelining others had direct consequences on the way in which soils are managed and related to. Historian Winiwarter (2014) has shown that the promotion and use of synthetic fertilisers in the 20th century were based on the idea of soil being only a substrate for holding and releasing the nutrients necessary for plant growth, rather than an ecosystem and web of vital interactions sustaining fertility. Ecological approaches to soils that had been developed in the first half of the twentieth century (Pessis, 2020) were sidelined in favour of physico-chemical approaches, following which, Winiwarter argues, 'Agricultural practice was changed in order to match the simplified theory that inorganic nutrients are the single most important factor in soil fertility' (Winiwarter, 2014, p. 114).

Finally, some scholars have combined this STS approach to political ecology to study the consequences of specific scientific framings, for example to study how soil scientific knowledge is then used to establish regulations which bear on the life of local soils and communities. They have insisted on how interactions between these different knowledge claims result in tensions and debates regarding how soils should be managed and protected. Hence, the framing and diagnosis of a specific soil-related phenomenon often result in specific recommendations for land use or agricultural practices, which in turn may impact soils and local communities. For example, in a study of the evolution of ideas about tropical soil formation in geomorphology, geographer Duvall (2011) has shown how representations of West African ferricretes (indurated, iron-rich soils) in colonial soil science were congruent with the notion, prominent in early 20th century colonial foresters, that African farmers and pastoralists had degraded the continent's vegetation and soils. Even though it was based on slim scientific evidence, and later proved to be wrong, this notion persisted for much of the 20th century because 'the representation of ferricretes as damaged soil also materialised the idea that European resource management techniques must be imposed to halt the environmental degradation supposedly caused by indigenous land management' (Duvall, 2011 :123).

Going beyond the anthropocentric limitations of earlier work in political ecology, which were criticised for giving too much importance to social discourses and practices and how they 'construct' soils, Duvall and other more recent authors attempt to do justice to the active capacities of soils themselves, such as their particular opacity, heterogeneity, and their diversity. Duvall insists that humans and soils interact in the production of scientific knowledge, rather than it being a human projection over a passive natural background. To him, soils are agentive in the production of knowledge because it was the long timescale of ferricrete formation – its specific mode of being and development – that made them seem inert to colonial scientists, which supported the view that they were degraded soils.

Be they located within environmental history, political ecology, ANT or broader STS approaches (see Table 1), recent scholarship on the politics of soil knowledge clearly emphasises the role of material properties of soils themselves in shaping the promises and anticipation of extraction. More broadly put, these approaches help get a sense of how processes of knowledge circulation and application participate in the joint production of soils and society – a cradle in which soils and society are mutually transformed in very concrete ways. Soils are not in the background anymore, as humans make them participate in the social fabric. However, the vitality of soils is acknowledged only inasmuch as humans themselves deploy ways of knowing them as dynamic and lively. Let us now turn to approaches in which soil agencies move more centre stage.

3. Soil new materialisms – caring for the living soil

The second set of literature, strongly inspired by the new materialisms scholarship (Whatmore, 2002; Bennett, 2010; Coole and Frost, 2010), multispecies ethnography (Haraway, 2008) and theories of care (Puig dela Bellacasa, 2017) (see Table 1), aims for a further step in the recognition that soil and subsoil are not just as a mere stock, or a set of inert resources for human use and exploitation. This literature focuses less on the impacts of various types of soil knowledge on how soils are understood, represented and managed, than on the capacity of soil ecological insights to open up soils, in particular soil biota, to new social conceptions, practices and attachments. It draws on the emergence and diffusion of soil biology and ecology, which gained new traction and institutional importance in the 1990s and 2000s, highlighting the importance of soil organisms, and their interaction with the chemico-physical processes that had received more attention until then (Lavelle and Spain, 2001; Coleman et al., 2004; Gobat et al., 2004). In the past ten years, part of this social science literature was also influenced by the dramatic rise of microbial ecology and environmental metagenomics developments that offered soil scientists new instruments and technologies to rapidly assess microbial genomes and metabolic capacities, thusproviding unprecedented access to the identities and roles of microbial associations in soil; (Paul, 2015). This literature in human and social sciences elaborates on the emergence and significance of new types of attention and relations toward soil among scientists, farmers, and soil practitioners.

At the end of the 2000s, writings by Hird (2009) and Helmreich (2009) pioneered a 'microbial turn' in social and human sciences by discussing the omnipresence and instrumental role of microbes in a variety of environments. They suggested how microbes unsettle our understandings of life mostly based on 'big like us' organisms and require us to open up our conceptions of life toward new possibilities of existence and agency, not based on the premise of well-bounded individuals and 'species', in order to reconsider the importance of symbiosis and cooperation instead of competition in biological evolution and adaptation. Further authors extended these insights into soil biota, in line with Darwin's observations about the role of earthworms in soil formation and social existence in the early nineteenth century.

Krzywoszynska emphasised that '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' (Krzywoszynska, 2020: 231). In a similar vein, Meulemans (2019), an ethnographer of scientific work, has described how soil ecologists seek to 'collaborate' with earthworms to build soil from urban organic and mineral wastes. Starting from the description of these scientists' interactions with soil and worms in the lab, Meulemans re-examines classical anthropological understandings of the distinctions between 'making' and 'growing,' which intersect with broader dichotomies between nature and technique in anthropological thinking. To Meulemans, soil ecologists' view of soil as a mix of particles continually digested and worked upon by a myriad of organisms allows to propose new anthropological understandings of what it means to make-with, live-with, and collaborate in an animated world, rather than in one of passive materials. Taking inspiration in Donna Haraway's notion of sympoiesis, which describes processes in which life forms are always 'making-with', or 'worlding-with, in company' (Haraway, 2016:58), rather than 'making themselves' (as in autopoiesis), such work builds on soil ecology (both as a set of theory and a way of engaging with soils) as a means to think differently about more-than-human dependencies, questioning common notions of making and growing, activity and passivity, organic and inorganic, or life and non-life.

The work of philosopher María Puig de la Bellacasa (2014, 2015, 2019) represents an important source of inspiration to these authors. Puig de la Bellacasa called to reconceptualising the role of soil as an invisible yet critical bio-infrastructure for all life on Earth, and to developing better attunements with the slow rhythms of soil organic matter regeneration – far from the rapid rotations of intensive

agriculture crops – on the basis of her observations with the permaculture movement. She called to developing more caring practices and approaches to soil, thus doing justice to the existence and capacities of soil biota and extending conservation and ethical concerns to non-human living beings as well as to the material processes of growth and self-regenerating.

Puig de la Bellacasa inspired a growing focus not only on the active capacities of the variety of living things – such as earthworms, fungi and bacteria – that inhabit, consume, digest, produce and transform soil (Meulemans, 2019; Krzywoszynska, 2020), but also on the active and dynamic nature of (top)soil and its particular brand of materiality as a heterogeneous mix of living organisms and dead or dying things, emphasising the role of decomposition in soil formation and regeneration (Lyon, 2020; Abrahamsson and Bertoni, 2014). These writings share the notion that understanding the materiality of living soils requires going beyond any strict separation between the biotic and the abiotic, the organic and the mineral, the living and the inert, the biological and the geological, as well as the natural and the social. They therefore account for the development of practices of soil attention, sensing and care both in traditional agricultural settings (Lyon, 2020) and contemporary agriculture (Krzywoszynska, Goulet, 2010), where conventional farmers' growing recognition of the foundational liveliness of soils is fostering new promises and hopes centred on the possibilities of remaking agriculture (Krzywoszynska, 2020 :229).

This body of work also includes a focus on urban settings, by investigating the emerging practices and communities aiming to build fertile soils out of lime and rocks unearthed by the extension of urban infrastructures (i.e. roads, parkings, airports…). By focusing on various experimentations and technics aiming to bring back life to soils seen as waste so far, this literature emphasises soils' potentialities for growing an exuberant and unexpected life within the ruins and interstices of urban expansion and soil sealing (Meulemans, 2020a).

This body of work is strongly committed to developing more attentive and ethical relations with soil as a living and lively ecosystem, with which human life is deeply entangled, thus echoing research on soil transformation and 'domestication' in soil sciences. Starting from the observation that soil types and classifications are akin to biological species, Amundson et al. (2003) asked for instance what fraction of soil species have been transformed and degraded by human activities and for human purposes in the case of the USA, leading to drastic changes in soil biodiversity, soil carbon content etc. Interest for urban soils in the human and social sciences also connects with the works in soil sciences demonstrating that urban expansion is a key factor of soil sealing, leading to a critical loss of habitats and biodiversity extinction (Scalenghe and Marsan, 2009; Seto et al., 2011).

By focusing on the sensory and performative aspects of organic processes such as plant or bacterial life, these approaches call for greater attention to the vulnerability of soil biota (for instance to landfill leakages: Hird and Clark, 2013) and to the relations and interdependence that link human life to the life of soils, which provide societies and all living things with all the means for their material existence on this planet. For a number of authors, compost has thus become a metaphor for the type of relations and togetherness in which living and non living components 'become with each other' without a pregiven plan or goal in a profusion of dynamic and regenerative transformations (Abrahamsson and Bertoni, 2014; Haraway, 2016).

However, some authors have remarked, soil life forms do not easily conform to the categories and presence-making technologies that have allowed conservationists to inventory and protect above-ground species and biodiversity (Yusoff, 2012). Indeed, classical policies and metrics of biodiversity conservation are based on the possibility to endow them with a stable identity, making it possible to protect them (for example through endangered species lists) and, above all, to represent them and care for them. As Hird and Clark pointed out, 'a great many of the living lineages that are now likely to be "disappearing" have never appeared to us in the first place… Too small, too obscure, too reticent to have graced our archives, these beings blink out of existence without ever making their presence felt' (Hird and Clark, 2013, p. 45). They propose to take the consideration of soil agencies yet one step aside by shifting the gaze away from a focus on organic matter toward deeper soils and the underground, in order to elaborate new theories and accounts of the materialities and agencies of those soils and their role in shaping human societies.

4. Soil decolonial studies – unravelling soils' powers and the intrication of soil and society agentivities

The third set of literature draws on continental philosophy, political ecology, decolonial studies (see Table 1) and the rich literature addressing the meanings of the advent of the Anthropocene – understood as an era marked by the unprecedented and transforming impact of human activities over the whole planet – in the humanities and social sciences. Authors aim to stress the role of land, soils and deep soils in shaping not only the material basis but also the political organisations and philosophical ideas of societies all over the development of humankind. They are inspired by scientific insights from soil ecotoxicology, geosciences and Earth system sciences – thus often they do not address soils directly, but rather the role of land and deep soils in the habitability of our planet. They often take soils (and deep soils for that matter) as prime examples of nature's alterity to (and precedence over) human affairs and as illustrating how human lives and institutions are embedded within and subjected to biogeochemical processes that also foster a permanent condition of human vulnerability. As such, they aim to unsettle anthropocentric accounts of society and to decolonize social sciences approaches from the belief in human exceptionalism inherited from the Enlightment philosophies.

We feel that this third strand of literature reflects an emerging attention and related theoretical thread in the humanities and social sciences, and think that it deserves to inspire a deeper and broader consideration of soil agency i.e. soil'simportant role in fostering and shaping various modes of living and thinking across human history.

Part of this scholarship starts from a criticism of soil new materialisms (i.e. the previous strand of literature) for viewing soil mostly as a site of promising profusion of life, a site of connections, entanglements, symbiosis and mutual flourishing between humans and soil biota (Ureta and Flores, 2018; Tironi, 2020). They highlight instead a different kind of soil agency, related to the rocky and mineral substrates in soils, emphasising the resistance of hard soils and the power of contamination of toxic soils. They emphasise the vitality of soil chemical residues – dusts, leachates – and their capacity to circulate in the environments and bodies and to contaminate humans, plants and animals (Gramaglia, 2020) and even soil microbiota itself (Hird and Clark, 2013). By scrutinising how toxic soils alter the life of people living on contaminated land, they remind us that soils are also characterised by pollution and contamination, and more generally not readily available to human relation and care.

This interest in soils whose agencies and transformations constitute a threat for humans is shared by human geographers and philosophers Nigel Clark and Kathryn Yusoff (Clark, 2011, 2017; Clark and Szerszynski, 2021; Yusoff, 2018), who proposed to take yet another step into unpacking the powers of soils – encompassing land and deep subsoils. Hence, Clark writes of 'in-human' soils in order to stress the difference with the 'more-than-human' entanglements and relations described by soil new materialisms authors, emphasising soils' capacities to unsettle human life and communities as well as to shape them. He stresses the crucial role of soil in providing human societies with the organic matter, the ore, and various types of combustibles instrumental not only to the development of agriculture, but also of arts and technologies such as metallurgy in ancient times, and fossil fuel-powered machines since the 18th century. Clark is also particularly interested in soils' upheavals, such as earthquakes and volcanic events, and their impacts on human life and communities. He discusses the cultural significance of the

discovery of plate tectonics in the 1960s and 1970s, suggesting that social thinkers should pay more attention to the fact that peoples and societies have always had to do with the incessant dynamism and violent upheavals of Earth crust. His key point is that soils' dynamism has had huge consequences both in creating a permanent state of bodily vulnerability attached to human life on the Earth, and in fostering the development of new political organisations and philosophical ideas aiming precisely to undermine this vulnerability and to highlight instead human autonomy, freedom and self-determination. To Clarke, the new awareness of the geological dynamism of the Earth, gained by 18th and 19th century scholars[1], partly fostered the historical development of Enlightment philosophies with their focus on freedom, reason and self-determination in the 19th century. Philosophers and scholars' attempt to deny the threats and anxieties induced by the new geo-scientific knowledge has been leading to a much exaggerated emphasis on humans' capacity to dispose of the material world, including soils and land as resources for cultivation, building and mining[2]. Clark suggests that, because of the legacy of these philosophies, Western social thinkers did not do justice to the capacity of soils both to destroy social communities, their institutions and moral values almost entirely, and to foster life-changing innovations in human ways of living and thinking – including land cultivation, metallurgy, and fossil fuel combustion.

In a similar line of thinking, Bobbette and Donovan (2018) addressed the history of the geological sciences and the role of geologists in shaping our understandings of what Earth and soils are, how they work and their relations with social and political processes. The contributions to their edited volume depart from the view that 'the earth is a surface upon and across which unfolds the dramas of sovereign territories and their politics' (p. 2) and focus instead on 'the earth's organisation into strata, and the depth of geological time and transformation' (p. 3), in order to address the intersections of geology and politics. This literature shares with the first set of literature an interest in scrutinising how scientific knowledge contributed to constituting Earth and soils as objects of knowledge and representation; yet it also shares with the second set of literature a commitment to paying more attention to soils' own materialities, agencies and dynamics. Compared with this latter literature, this last scholarship gives a new meaning to the idea of soil agency, which takes onboard much broader scales and temporalities than those considered by soil new materialism: soil agency is no longer associated with microbial life but rather with toxic dust durability and with the moves and upheavals of the Earth crust. As such, authors of the third set of research also contribute to suggesting the porosity of the boundary between the realm of the living and that of matter: they suggest the vitality, dynamism and agency of soils and how their composition and genesis demonstrate the constant interactions and hybridisation of matter and living entities. However, authors here are not so much interested in establishing more ethical relations with soil biota than with unpacking the political and cultural significance of soils' powers and forces – leading to revisiting the vulnerability of human organisations, institutions and ideas.

On the other hand, this literature also suggests that the possibility of the development of humankind is closely embedded within the material capacities offered by soils. Clark and Yusoff's key argument is that the contemporary extraction of chemical resources (such as phosphates or lithium) from soils should not be understood only in terms of the rise of human capacity to make and govern soils as resources (cf. the first body of literature): those developments have also been made possible by the materialities and powers of soil itself, by its capacity to process and store fossilised organic matter over the very long term, for instance. They argue that we need to 'geologize' human and social thinkers' accounts of social history i.e. to do justice to the fact that what is often understood as human innovations and social creativity has been inspired, conditioned and shaped by the material capacities and agency of soils. Inspired by this, Granjou and Salazar (2019) for instance pointed that our narratives of climate change may be too much focused on human-induced increase of greenhouse gases, and should pay more attention to soil's role in fostering brutal and irreversible tipping points such as permafrost thaw.

While its focus on soil is quite broad and encompasses both land, deep subsoils and the Earth crust, we think that this last body of work sketches new avenues to think of human/soil relations in a different, and innovative way, by fostering better accounts of the deep entanglementof soil-related and society-related dynamics and agentivities.

5. Discussion and conclusion

With this review, we wanted to sketch some of the key contributions and tensions of the growing scholarship on soil in the human and social sciences in the last two decades. Observing a rich and growing amount of research that unpacks various configurations of human/soil relations, we proposed a reading of this scholarship based on three groups of literature – also knowing that the ideas and writings often tend to be more permeable to exchanges and circulation than what our review has been able to account for. However, our key goal was not to give an all-encompassing view of the lineages and circulation that link them together: instead we aimed to highlight an ongoing conversation regarding how this literature has been considering the material properties and agencies of soils. Table 2 offers an overview of the three sets of literature by outlining the soil science fields and approaches they are in line with, the theories and frameworks in the humanities and social sciences that they rely on, their main ideas and contributions, and eventually the way they address soil materialities and agencies.

We argue that there has been a growing concern in the human and social sciences for considering not only how various societies and peoples engage with soils, but also, symmetrically, how soils contribute to shaping social communities and organisations. As they increasingly recognize that soils are not just a mere stock, or a set of inert resources for human use and exploitation, but are instead active, dynamic and vulnerable systems with their own materialities, agencies and dynamics, the human and social sciences also tend to build new potential linkages and bridges with the soil sciences around the consideration of scientific knowledge on the nature, functioning and evolution of soils.

Concerns for the microbial life and functioning of soil are for instance at the core of the development of soil new materialisms and its focus on the agency and vulnerability of soil biota; it is eventually deepened and expanded in the third group of literature focusing on the power of soils – encompassing both land and deep soils – both to destroy and constitute social communities, technical innovations and philosophical ideas. Social scientific scholarship related to soil is thus more and more involved in the endeavour to unsettle the overarching focus of the human and social sciences on the influence of human categories, discourses and activities on the constitution of the material world – rather than the other way around.

Here, we think it is important to note that the increasing uptake of soil, soil issues and soil knowledge in social and human sciences cannot be reduced to a case of applying existing social theories and frameworks to a new object, i.e. soils. While anchored in a range of existing theories and fields, the emergence of social soil studies clearly contributes to an

[1] For instance, Clark discusses the major shift in the temporalities considered by European philosophers at the time, away from the notion of a few millennia testified to by religious writings, to the consideration of deep time stretching back to hundreds of millions year back, during which there were no humans on the Earth, leading philosophers to long-lasting anxieties over the place and the fate of humankind on this planet (see: Clark, 2011, 2017, and 2020).

[2] Yusoff (2018) also stressed that the extraordinary expansion of soil mining activities in the 18th century was not only key to the emancipation and enrichment of Europe through the Industrial Revolution, but also to the rise of new ideas regarding the inert and passive character of matter, ready to be extracted, shaped and used – thus contrasting with the activity, creativity and self-determination of humans.

Table 2
Overview.

	Politics of Soil knowledge	Soil new materialism	Soil decolonial studies
Linkagewith soil science disciplines	Agronomy, pedology, soil mapping, soil sciences	Soil ecology, agronomy, environmental sciences	Soil ecotoxicology, Earth system sciences, geosciences
Social science theories	Actor-Network Theory, Environmental History, Foucauldian theories, Political Ecology	New materialism, Multispecies Ethnography, Care theories	De-colonial studies, Anthropology, Continental Philosophy
Main contributions	Soils are not pre-existing resources but constituted as knowable, manageable and exploitable; they are known and understood in various, partly conflicting ways.	Emphasises the lively and vulnerable nature of the soil; calls to developing better recognition and care practices toward the living soil.	Soils and deep soils have participated in shaping the material basis, political organisations and philosophical ideas of peoples and societies throughout the development of humankind.
Consideration of soil materialities and agencies	Analyses knowledge production and soil management practices about soil – while also accounting, to a certain degree, for soil materialities and agencies	Emphasises the life and activity of soil biota and the reciprocity between soil and human flourishing	Addresses the power of soil material strata and its role in constituting human communities, arts and philosophical ideas

increasing concern for rethinking the place of the natural and material world in social and human scientific theories and concepts and achieving better theoretical and empirical accounts of the co-constitution of society and the material world. Obviously, the writings we presented in this review related to soil and soil issues partake in a much broader move within the humanities and social sciences, away from an 'over-emphasis on discourse and power [which] often overlooked the unique capacities of environments and non-human actors to act politically' (Bobbette and Donovan, 2018: 25). As these authors further stated, 'scholars have since moved towards insisting on understanding non-human agency (…) [thus] allowing the world to properly, fully exist independently of human thought/consciousness' (Bobbette and Donovan, 2018: 25–26). At the heart of this literature is clearly an ongoing attempt to decentre the place of humans in social and human scientific work. It opens up new pathways to put more emphasis on soil itself without renouncing the critical capacity of human and social sciences to foster critical insights and alternative futures likely to unsettle taken-for-granted views on what soils are and how they work in relation to social existence. It also opens up to new potentialities for communicating across the soil sciences and the human and social sciences, in line with recent attempts to cross disciplinary boundaries and foster interdisciplinary insights into soil and soil issues (Lago et al., 2019; Baveye, 2021).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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