frontiers | Frontiers in Sustainability

TYPE Policy and Practice Reviews
PUBLISHED 13 March 2023
DOI 10.3389/frsus.2023.1115238

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Sustainable Organizations, a section of the journal Frontiers in Sustainability

RECEIVED 03 December 2022
ACCEPTED 22 February 2023
PUBLISHED 13 March 2023

CITATION
Raffoul AW (2023) Listen to the science! Which science? Regenerative research for times of planetary crises. *Front. Sustain.* 4:1115238. doi: 10.3389/frsus.2023.1115238

Listen to the science! Which science? Regenerative research for times of planetary crises

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In situations where scientists disagree, which science should decision-makers listen to? This article argues that we should listen to "regenerative research", that is, research (1) whose *objective* is to regenerate our relationship to the land and to each other (rather than dominating nature), (2) whose *worldview* acknowledges the interconnection between humans and non-humans (rather than assuming a separation between humanity and nature), and (3) whose *processes* are democratized (instead of including but a narrow circle of researchers). We should listen to regenerative science not because it is suited to the interests of politicians or activists, but because it is most likely to be beneficent, rigorous, and objective. In addition to granting scientists new responsibilities, such as engaging in public action, the climate and ecological crises therefore also require us to critically reflect on the core of our work: the knowledge we generate.

KEYWORDS

science, climate crisis, ecology, democracy, regenerative research

Introduction

In 1949, two of the first international scientific conferences on the environment were held in parallel on the shores of Lake Success, New York (Jundt, 2014). The UNSCCUR[1] focused on ensuring the effective exploitation of earth materials to safeguard a sustainable supply of resources for the economy. In stark contrast, the ITCPN[2] promoted the protection of nature understood as "the preservation of the entire world biotic community" (Jundt, 2014, p. 57). In 1983, the National Academy of Science report "Changing Climate" looked more like two reports than one. While climate scientists raised the alarm about rapid anthropogenic climate change, economists minimized the impact of raising emissions and promoted a "wait and see" approach (Oreskes and Conway, 2015, p. 177). Today, a broad scientific consensus on the urgency of acting to mitigate climate change has emerged. However, scientific recommendations on how to do so at times remain contradictory. The Sixth Assessment Report of the IPCC (2021) is a case in point. While Working Group II calls for transformational societal and economic changes and recognizes the value of indigenous and local forms of knowledge, Working Group III promotes the large-scale deployment of yet-unavailable carbon removal technologies.

In cases where scientists disagree, what does it mean to "listen to the Science"? Quite often, like in the examples above, policy-makers' approach has been cherry-picking the most

1 UN Scientific Conference on Conservation and Utilization of Natural Resources.

2 International Technical Conference on the Protection of Nature.

convenient science—often instrumentalizing it to serve ideological preferences and interests. In the current climate and ecological emergency (CEE), this approach makes us run the unacceptable risk of failing to limit the increase of global temperatures or the continuous collapse of ecosystems. Building on the literature on the philosophy, history, and sociology of science, this article provides a framework for deciding which voice to listen to when scientists disagree.[3]

The article argues that decision-makers should listen to *regenerative research*. That is, science (1) whose objective is to regenerate our relationship to the land and to each other (rather than dominating nature), (2) whose worldview acknowledges the interconnection between all earthly beings (rather than assuming the separation of humanity and nature), and (3) whose processes are democratized (instead of including but a narrow circle of researchers). We should listen to regenerative science not because it is more suited to the interests of politicians or activists, but because it is the most likely to be benevolent, rigorous, and objective.

This analysis has implications for policy-makers, but also universities, funding bodies and researchers. While the reflection on the role of academia in a climate crisis has largely focused on adding new responsibilities to scholars—reducing their carbon footprints, refusing fossil fuel funding, or speaking up publicly about the inconvenient implications of their findings—this paper suggests that the CEE calls for a reflection on the core of the scientific endeavor: the type of knowledge we generate.

After reviewing the current discussion about research ethics in a climate crisis, the article moves toward discussing some issues in the dominant paradigm of modern science, and its alternative: regenerative research.

New ethical norms for scientists in the CEE

The question of what is "good" science—the science we should listen to—has traditionally been the object of research ethics. The main reflection on research ethics can be roughly summarized in three big principles: *respect*, *rigor*, and *responsibility* (UK Government Office for Science, 2007). According to these principles, scientific research is "good", when it is (1) *benevolent* because it respects the "human subjects" involved in the research process, (2) *credible* because it is rigorous in its methods and data collection processes, and (3) *relevant* because it listens to societal needs and proposes solutions based on an objective analysis.

In recent years, some sectors of academia engaged in a reflection on the consequences of the CEE on research ethics. Three new norms are emerging from this reflection. They can be understood as the broadening of the three originals principles of research ethics. A first one is the imperative, for academia, to stop its own carbon emissions. Some examples of its application include: scholars aiming to fly less (e.g., Nevins, 2014), universities adopting "green campus" plans, or academics questioning the energy consumption of scientific equipment, ranging from super-computers (Bender et al., 2021) to circular particle colliders (Janot and Blondel, 2022). The principle of respect is thus broadened to encompass a concern for the long-term and unintended consequences of the research on the environment (Gustafsson et al., 2021).

A second emerging norm aims to protect science from the undue influence of fossil fuel lobbies. In March 2022 more than 500 scholars signed an open letter asking universities to refuse funding from the fossil fuel industry[4] — a demand relayed by student protests in various universities. The principle of rigor is thus broadened to include the concern that receiving funding from fossil fuel companies risks introducing biases in research, in particular in times when considerable efforts are deployed to sow doubt on science, engineer ignorance, or distort scientific findings to serve industrial interests (Oreskes and Conway, 2015).

Finally, a third axis of reflection regards the visibility of climate science. Many called for scientists to communicate their research findings and their consequences more vocally in the public debate (Oreskes and Conway, 2010), including by using civil disobedience (Gardner et al., 2021). This prescription implies a broadening of the principle of responsibility, demanding scholars to stand up for the societal implications of their findings—even (or especially) when those have particularly far-ranging political implications.

These new ethical norms are essential to ensure universities play a positive role in addressing the CEE. However, they focus on peripheral aspects of academic research and only marginally engage with the core of the scientific enterprise: the knowledge we generate. These principles are rooted in a vision of scientific knowledge as relatively unproblematic. This optimistic outlook overlooks a large critical literature in the history, sociology, and philosophy of science that shed light on the contribution of science and engineering in the historical process that led us to the CEE (Merchant, 1980). It also ignores the indigenous voices who criticized western science as an instrument for colonialism and imperialism (Ake, 1982; Smith, 2021).

To complement the three ethical principles that emerged in the literature, this article proposes a reflection on the ethical implications of the CEE for scientific knowledge itself. The starting point is acknowledging that, strictly speaking, there is not one *Science*, but multiple *sciences*—which have played and continue playing different roles in society (Latour, 2004; Stengers, 2018). From the pioneering work of Joseph Fourier (1786–1830), Eunice Newton Foote (1819–1888), John Tyndall (1820–1893), and Svante Arrhenius (1859–1927)—who identified and quantified the "greenhouse" effect of carbon dioxide—to the latest IPCC report, scientists have been and continue to be at the forefront of those raising the alarm on the CEE. Yet at the same time, science played a significant role in the constitution of the worldview, knowledge, and technologies, that led to an over-exploitation of the Earth and non-western populations (Merchant, 1980). If science is not one, which science should we listen to?

Next section reviews the critique of modern science, while the following identifies an alternative scientific tradition—regenerative research—that should be emphasized in the current context.

3 This research question implies that this article is specifically concerned with the interaction between science and society, rather than with the tradition of fundamental science and its objective to generate knowledge out of curiosity or a sense of aesthetics (e.g., abstract mathematics).

4 https://fossilfreeresearch.com

Modern science and the origins of the CEE

A relatively large literature in the history, philosophy, and sociology of science criticizes modern science for the role it plays in constituting the worldview, knowledge, and technologies that led us to and continue fueling the CEE. The critiques formulated in this literature focus on the objective, worldview, and processes of modern science.

Progress as domination of nature

A first set of critiques focuses on the *objective* pursued by the modern scientific project. Modern science rests predominantly on a certain vision of progress, understood as improvement of human welfare through the domination of nature and the emancipation from its constraints (Charbonnier, 2021). Since Francis Bacon, science is understood as one of the main drivers of this idea of progress. The knowledge of the laws of nature allows humans to tame, control, subjugate, and engineer nature (Merchant, 1980). In this view, "scientific and technical expertise will benefit humankind by rendering the non-human world less threatening, more predictable, and more profitable" (Yao, 2022, p. 7). Science is thus understood as "an instrument of awesome power allowing its holder to improve reality" (Bauman, 1989, p. 70). And since non-Europeans, women, or indigenous and LGBTQ+ peoples are often excluded from the concept of humanity (Braidotti, 2019), the project of mastery and subjugation also feeds social domination and imperialism (Jahn, 1999; Gaard, 2001; Bowden, 2009; Sultana, 2022).

Based on this definition of progress, scientific and technological innovation is considered inherently good despite its destructive effects (Godin, 2015). Research on a variety of technologies that have damaging effects on the environment—such as the steam and the internal-combustion engines (Malm, 2016), agrochemicals (Carson, 1962) and GMOs (Muir and Howard, 1999), dam systems (Schmutz and Moog, 2018) or nuclear weapons (Higuchi, 2020)—is thus considered coherent with the principle of respect. The impulse to dominate nature and populations found perhaps its most radical realization in eugenics, the attempt to engineer human genetics (Micklos and Carlson, 2000). Today, it finds a new expression in "effective altruism" and "long-termism", who attempt to redefine ethics based on a an unlimited belief in the mathematical predictability of the world (Srinivasan, 2015). A perhaps even more problematic example is eco-modernism and its celebration of the "good Anthropocene," based on a seemingly limitless faith in humanity's ability to deliberately manipulate the climate *via* geoengineering to ensure optimal living conditions for humanity (Hamilton, 2016).

Faced with the daily reports of the destructive consequences of the CEE, we can no longer maintain our faith in the vision of progress as mastery of nature. While this project undeniably delivered large improvements in welfare for a section of humanity, it relied on the unsustainable (and unethical) exploitation of the earth and of non-western people (Krause, 2020). In light of this historical experience, it thus appears at best unlikely that a science based on the objective of subjugation of nature can be truly benevolent and fulfill the ethical principle of respect.

A mechanistic worldview

A second focus of the critique against modern science concerns its *worldview*. Indeed, the objective of domination of the earth was made possible by the mechanistic worldview that underlies modern science. Nature is understood (in a Newtonian fashion) as a big machine, constituted of individual pieces which are connected by natural forces such as gravity or electro-magnetic forces. Because the interactions between these pieces are ruled by deterministic, universal, and objectively quantifiable laws of nature, this approach considers that the future can be predicted accurately (Best, 1991). This radical objectivism separates the observer from the observed, leading to the idea (associated with Descartes) of a disconnection of the subject from the object, the mind from the body, the conscious from the inert. This worldview thus leads to the idea of a stark separation between humanity and nature, that became a cornerstone of modernity (Latour, 1993).

The mechanistic worldview removed the ethical and intellectual obstacles to the ruthless exploitation of the Earth (Merchant, 1980). Indeed, the metaphor of nature as an automat leads to a conception of our planetary habitat as an inert resource, composed of dead matter, available for valorization by humans and amenable to engineering. Moreover, this worldview paves the way to a reductionist science that conceals important interactions and interconnections, because it assumes that some parts of the "machine" can be studied in isolation from others. Separating the (human) economy from the (natural) climate, neo-classical economists for example judge it to be reasonable to assume that "about 90% of GDP will be unaffected by climate change, because it happens indoors" (Keen, 2021). Systems of ecological valuation such as calculating "ecosystemic services" are criticized for reducing their object to economic assumptions, while dismissing other important ecological functions and interconnections (Norgaard, 2010). In the debate about intensive forestry in Sweden, stakeholders adopting a mechanistic worldview justify intensive forest exploitation by focusing on forests' role as carbon sinks, while ignoring the carbon emissions of clearcutting or its effects on biodiversity (Lidskog et al., 2013).

As tropical storms leave thousands of people without electricity, floodings wreck entire cities, heatwaves take the life of our grandparents, and water scarcity threatens our agriculture (Gasper et al., 2011), the idea of a disconnection between nature and humanity appears more and more like a dangerous fantasy. As Amitav Gosh puts it, "our earth is doing our thinking for us" (Malmuth, 2021): the mechanistic worldview is proven wrong by the unfolding of the CEE itself. Rather than separated, we realize that we are dependent on non-humans (Latour, 2017) and that "natural forces and human forces are so intertwined that the fate of one determines the fate of the other" (Zalasiewicz et al., 2010, p. 2231). Because it results in the dismissal of important variables and interconnections, that nowadays violently remind us of their existence, it is unlikely that the mechanistic worldview leads to a science that respects the ethical principle of rigor.

Absolute knowledge

A third axis of critique is focusing on the *process* of doing science. Modern science is built on the idea of a strong distinction between scientists as knowers and non-scientists as ignorant, restricted to the domain of opinion, irrationality, and superstition (Latour, 2004). By virtue of the scientific method—defined in terms of verification or falsifiability—scientists are deemed to produce the only form of valid, absolute knowledge. In this understanding, scientific knowledge is conceived of as a "view from nowhere" (Haraway, 1988), objective and value-neutral. The scientific process is thus viewed as an apolitical process, where what is researched and how the research is conducted is irrelevant as long as knowledge is accumulated. "Advances in science are taken to be the outcome of investments employing trained people to apply the scientific method to accumulating knowledge, which now can be equated with information, with metrics being developed to measure efficiency in its production" (Gare, 2022, p. 260).

Under its pretenses of neutrality, this vision of knowledge however risks hiding biases and conflicts of interest, making a particular perspective look universal. Against the predominant conception of scientists as objective knowledge producers, the feminist literature argued that, as any other humans, individual scientists do have a certain point of view, values, and assumptions. Consequently, a lack of diversity in the scientific community can lead to biases in the scientific outcomes (Harding, 1986). Such biases can take the form of sexism, racism or classism in scientific theories—as in the case of the "limited energy theory", developed by Edward H. Clarke in 1873, according to which women should not engage in higher education as it would diminish their fertility (Oreskes, 2021, p. 76). Biases can also result from uneven coverage or selection bias. For example, women's health issues have suffered from a chronic lack of funding in the US (Mirin, 2021). Similarly, the science of extreme weather event attribution has predominantly focused on the Global North, even though the severity of such events is higher in the Global South (Otto et al., 2020). More broadly, indigenous scholars formulated stark criticism of science's role in contributing to the imperial project by imposing western concepts and ideologies to the colonized, and denying the legitimacy of indigenous knowledge, while appropriating it for the benefit of the colonizer (Ake, 1982; de Sousa Santos, 2015; Smith, 2021).

These critiques suggest that rooting the objectivity of science only in the scientific method carries the risk of invisibilizing biases, contributing to the production and reproduction of (environmental) racism, sexism and classism (Gaard, 2001). Such scientific biases can be exacerbated when there are close ties between researchers and the industry—as was for example documented in biomedical research (Krimsky, 2004) or in research on geoengineering (Hamilton, 2013). Since it listens to specific interests rather than the general interest, a science that is not sufficiently diverse and does not question its biases can only be relevant to a specific group of people rather than to society at large. As such, modern science cannot fully fulfill the ethical principle of responsibility in the CEE.

In summary, modern science has been criticized for pursuing an *objective* that cannot credibly result in a benevolent science, based on a *worldview* that does not deliver rigorous analyses, and *via processes* that do not lead to objective and societally-relevant results.

Regenerative research

These critiques must be taken seriously. However, they are best understood as addressing one specific scientific tradition. As such, they do not demand abandoning the scientific project altogether. Rather, there has always been alternative tendencies within the scientific project itself, rooted in other objectives, worldviews, and processes that condone another relationship to the earth. These other approaches to science can be loosely grouped under the label "regenerative research".

Progress as regeneration

Regenerative research preserves the *objective* of progress as improvement of human welfare, but sees the avenue toward this progress not in the domination of nature, but in the regeneration of the relationships between humans, and between humanity and the Earth. Where modernity sees itself as breaking with a past of vulnerability and ignorance, this alternative conception sees progress as a break with a period where a relatively small group of humans' extractivist relationship to the world led us on the verge of catastrophe. Regeneration does not imply a return to an idealized past where humanity would have lived in a state of harmony with nature. Nor does it involve the restoration of a "pure" nature, untouched by human activities. Rather, it means healing the strained *relationships* between humans and non-humans and between humans themselves; it consists in inventing new relationships that are conducive to the mutual flourishing and the self-realization of both humans and non-humans, as individuals and collectives (Martínez, 2017; Blanco-Wells, 2021). This objective is rooted in the acknowledgment that human wellbeing is inextricably interconnected to the wellbeing of other humans and of the land. Regenerative science is thus based on an ethics of care and of reciprocity: the researcher endorsees the role of a healer (Chilisa, 2007), taking care of those who take care of us (Kimmerer, 2013a).

This objective of regeneration is guiding a diversity of existing research, only a handful of which can be provided here as examples.

- *Restoration ecology* aims to revitalize ecosystems that were damaged by human exploitation, such as natural forests or peatland. While rooted in an understanding of the history of place, restorative ecology acknowledges that ecosystems are always changing. It therefore does not aim to reconstitute the original ecosystem, but rather to heal the relationship between species, restoring the function and interactions in ecosystems, and rebuilding self-standing and self-reinforcing ecosystems (Higgs, 2003; Jackson and Hobbs, 2009; Kimmerer, 2011).
- *Regenerative agriculture, agroforestry, permaculture, or urban agriculture* explore ways to produce food while fostering

biodiversity, building healthy soils, increasing water quality, and capturing carbon (Rhodes, 2017).

- *Regenerative design and agriculture* studies how to construct buildings integrated in place, that not only aim to reduce the environmental harm caused by construction (sustainability) but also seek to actively improve the health of ecosystems (Todd and Todd, 1994; Van Der Ryn and Cowan, 1996; McDonough and Braungart, 2002). The field "uses the millions of years of engineering and evolution as the foundation for a regenerative structure", designing dwellings *with* rather than *on* the landscape (Littman, 2009, p. 1).
- Research on *language revitalization* aims to revive the use of languages endangered by globalization or colonization. From this perspective, language is understood as one factor contributing to the wellbeing of a community, embedded in a broader network of relationships connecting humans to their habitat (Grenoble and Whaley, 2021).
- *Ecological economics* moves beyond the dominant orthodoxy to envision an economy that serves the common good and fulfills essential needs, while respecting planetary boundaries (Herman and Cobb, 1994; Raworth, 2017).
- Research on various forms of conflict resolution, such as the diverse field of *environmental peace and conflict research*, provides insights in the multiple ways peace in human societies is connected to the health of their environment (Ide et al., 2023).
- In the social sciences more broadly, the field of *transformative research* proposes a methodology for research to contribute to the elimination of exploitation based on ethnic, gender, or age-group; formulating research questions and conducting the research in partnership with the researched communities (Mertens, 2008).

Regenerative science preserves the objective of progress as improvement in human welfare, but proposes another way to attain it— the regeneration of the relationships between humans and non-humans. Since it preserves the main objective of improving human welfare, but rectifies the strategy to attain it, regenerative research is neither more, nor less value-laden than the dominant modern science. While very different, the forms of research it encompasses can be complementary in a broadened process of reciprocal restoration understood as "the mutually reinforcing restoration of land and culture such that repair of ecosystem services contributes to cultural revitalization, and renewal of culture promotes restoration of ecological integrity" (Kimmerer, 2011, p. 258). By its existence and its practice, regenerative research signals the possibility of positive relationships between humans and non-humans, where scientific knowledge serves the process of healing and regeneration (Higgs, 2003). This change of strategy—from domination to mutual restoration—makes regenerative research more likely to be truly benevolent and respectful in the context of the CEE.

An interconnected world

Regenerative research is rooted in a processual and relational *worldview* that acknowledges the interconnection of humanity and nature. In this processual worldview, reality is understood as constantly in a process of emergence and becoming (Whitehead, 1987; Bergson, 2023). The world is seen not as stable and harmonious, but as inherently chaotic and complex (Best, 1991). Change can be non-linear, where small causes can lead to big effects. Matter is no longer inert, but becomes active, vibrant (Bennett, 2010; DeLanda, 2015). The world is no longer finite and predictable, but open and self-creating. In this relational worldview, the part is not conceived in isolation from the whole; the individual is not understood separately from the community (Deleuze and Guattari, 1987). Descartes' adage "I think, therefore I am" is replaced by the Bantu concept of *Ubuntu*, sometimes translated as "I am because we are" (Chilisa, 2019, p. 99). Humans are seen as dependent on the land for subsistence, livelihood, and health; but the land is also seen as in movement, shaping humans and shaped by them (Latour, 2017). The boundaries of the community relevant for our ethics are enlarged "to include soils, water, plants, and animals, or collectively: the land. [...] The role of Homo sapiens [is redefined] from conqueror of the land-community to plain member and citizen of it" (Leopold, 1987, p. 204).

Such a worldview results in a science that is more holistic, or emergent, in the sense that it seeks to understand complex systems where the properties of the whole cannot be reduced to those of the parts. Some examples of the emergence of such a post-dualist worldview in various disciplines include the following:

- In *physics*, this alternative tradition emerged with Joseph Fourier's thermodynamics (Prigogine and Stengers, 2018) and Niels Bohr's quantum mechanics (Best, 1991), which marked the shift from a deterministic to a more probabilistic science.
- In *biology*, Darwin's evolutionary theory similarly introduced an understanding of reality as open, self-organizing, and with emerging complexity; and contributed to relocate humans within nature (Hodgson, 2002).
- In *mathematics* and *computer science*, chaos theory and complexity theory study the behavior of complex systems, sensitive to initial conditions (Morcol, 2001).
- *Ecology*—often called the "subversive science" for it displaces the focus of analysis toward the interrelations between beings and their environment (Hardin, 1985)—is perhaps the most important scientific realization of an interconnected worldview.
- Some branches of *Earth system science*, such as research on planetary boundaries, challenge the mechanistic worldview by conceiving of the earth as a "system with complex, vulnerably interrelated parts" (Warde et al., 2018, p. 154-158) and by taking into account non-linearity, in the form of tipping points and feedback loops (Steffen et al., 2015).
- In *social sciences and humanities*, a variety of new approaches seek to move past the dualism between humanity and nature. These include, amongst others, actor-network-theory (ANT) (Latour, 2007), new materialism (DeLanda, 2015), object-oriented-ontology (OOO) (Harman, 2018), environmental humanities (Sörlin, 2012), and ecosemiotics (Maran, 2020).
- Finally, this worldview is predominant in forms of *indigenous and southern epistemologies* that gain increasing recognition in various academic disciplines (de Sousa Santos, 2015; Escobar, 2016; Chilisa, 2019).

Because it breaks with the idea of separation between humanity and nature, and instead accounts for the entanglement of destinies of all earthly beings, rendered painfully visible by the Anthropocene (Zalasiewicz et al., 2010), regenerative science is likely to be less reductive than modern science. This approach restitutes the complexity, historicity, contingency, politics, and agencies at play in any phenomena. While mathematical models and simulations are still elaborated and useful, these are not confused with faultless descriptions of reality (Cartwright, 1984; Thompson and Smith, 2019). For these various reasons, a regenerative science based on a relational worldview is more likely than modern science to respect the ethical principle of rigor.

A democratized science

Regenerative research is also characterized by a scientific *process* that is democratized. While it does not hold that scientists should abandon their ambition to reach objective scientific facts, regenerative research is based on a social understanding of objectivity—which Harding (1986) called "strong objectivity." This perspective recognizes that scientists always occupy a specific social position, which comes with specific values, biases, and blind-spots. Knowledge is always situated, scientists always see the world from somewhere (Haraway, 1988). Scientific knowledge gains its objectivity through the formation of a scientific consensus: a long process of contradiction during which "competent colleagues" formulate objections to a scientist's claims until everyone is convinced (Stengers, 2018). Thus, the greater the diversity of colleagues formulating objections, the most likely it is that potential biases will be corrected and a greater degree of objectivity will be achieved (Longino, 1990/2020). As Merleau-Ponty (2013) puts it, the most objective account of a house is not that of the house *seen from nowhere*, but rather that of house *seen from everywhere*.

This more expensive understanding of objectivity is realized in various ways.

- First, regenerative research seeks to achieve a consensus in a broad and diverse *community of researchers*. Diversity in disciplines, departments, and laboratories is thus essential. The IPCC constitutes perhaps the most ambitious attempt at formalizing the emergence and formulation of a global scientific consensus on a given object of study (i.e., climate change).
- Second, because it abandons the premise that scientific knowledge is the only valid form of knowledge, regenerative research is also open to *other relevant forms of knowledge*. One such form of knowledge is indigenous knowledge, accumulated by indigenous communities through centuries of close contact with the land, and which can enter in a dialogue with scientific knowledge—for example in the fields of regenerative ecology (Kimmerer, 2013b) or sustainable food systems (Antonelli, 2023). Another form of relevant knowledge is the expertise of competent practitioners, such as farmers, fishermen, nurses, peacebuilders, or activists, whose first-hand, daily experience can complement the more distant perspective of scientific knowledge (Finlayson, 1994; Wynne, 1996; Escobar, 2016).
- Finally, regenerative research also seeks to consult those—human and non-humans[5]—that are *most affected by the phenomena under study* or the technologies under development, and who are therefore in the best position to assess the consequences of the research or its societal relevance (Silvertown, 2009; Garlick and Levine, 2017; Fornstedt, 2021; Pamuk, 2021). This is realized in Participatory Action Research or in Citizen Science, consulting for example patients in medical research or indigenous communities in research on Aids (Epstein, 1996; Chilisa, 2019).

The integration of this multiplicity of situated knowledges serves to build a "more adequate, richer, better account of a world, in order to live in it well and in critical, reflexive relation to our own as well as others' practices of domination and the unequal parts of privilege and oppression that make up all positions" (Haraway, 1988, p. 579). In this sense, regenerative research is likely to be more objective and thus societally responsible than a science that is unaware of the role values might play in the formulation of its findings.

Implications

In situations where scientists disagree, which science should decision-makers listen to? After reviewing the critiques of modern science, this article identified an alternative tradition that should be privileged: "regenerative research." Regenerative research rests on (1) a vision of progress understood as improvement in human welfare through the regeneration of our relationship with the land and with each other, (2) a worldview that takes into account the complex web of interconnections between humans and non-humans, and (3) a process that aims at the formation of a broad-based consensus between a diverse group of scientists, in dialogue with other forms of relevant knowledge (such as indigenous knowledge) and in consultation with those most affected by the research.

The analysis suggested that regenerative research should be listened to not because it satisfies the interests of particular groups, but rather because it is more likely to be benevolent, rigorous, and responsible. When faced with a scientific proposition, decision-makers should therefore ask questions such as: What is the vision of progress that underlies this piece of research? (Dominative or regenerative?) In what worldview is this research rooted? (Mechanistic or relational?) Who was consulted in the research process and who supports these findings? (A single scientist, a narrow community supported by industrialists, or a large and diverse epistemic community?).

The article contributes to the recent reflection on the ethical responsibilities for scientists by paying attention to the implications of the CEE for the core of academic research: the knowledge we generate. While regenerative research is perhaps more needed than ever in the CEE, many obstacles persist to its realization.

5 Scientists can represent non-humans in this consultation process by playing the role of "spokesperson" for their object of study (Latour, 2004).

These obstacles include, amongst others: the lack of recognition and funding of regenerative research; the commodification of knowledge; the rise of private research funding, corporate sponsorships, and university partnerships with the industry; the resistance to interdisciplinary work; the fragmentation of research in hyper-specialized disciplines; the reluctance to acknowledge issues relative to values in science; and the enduring skepticism toward non-scientific forms of knowledge.

As such, the argument also carries implications for universities, research funding bodies, and scholars themselves. These actors should ask themselves: Which research questions do we prioritize? Who decides what research is pursued? What are the mechanistic foundations of our theories and how can these be re-rooted in a non-mechanistic worldview?[6] Is our scientific community diverse enough? And which forms of knowledge are consulted in the research process? Importantly, these reflections should not be pursued only on research on environmental issues, but rather throughout the academy.[7] While the vision of regenerative research is presented here in broad strokes, scholars should think about how to implement it in their own specialized disciplines.

Alfred North Whitehead described the role of universities as "*creating the future*" (Gare, 2022). In the world of modern science, the question of which future we create is not open for deliberation. Because reality is conceived as predictable, the future appears already written, inevitable, closed (Hulme, 2011). Because it reduces the world to laws of nature, market mechanisms, or technological issues to be solved by technological means, modern science depoliticizes the objects it studies (Swyngedouw, 2013; Malm and Hornborg, 2014). In this context, invoking science serves to close the political debate. Decision-makers are asked to simply follow the absolute knowledge of scientists. The relationship between science and democracy is thus strained (Pamuk, 2021; Rovelli, 2021).

By contrast, regenerative research makes the creation of our shared future thinkable. Its processual and relational worldview opens the possibility of the emergence of a variety of futures, and sheds light on the power relations that permeate the decisions leading to one or the other. Regenerative research thus cannot be invoked to bring the political debate to an early closure. Rather, it always opens the debate, brings new issues to the political agenda, and gives voice to different (human and non-human) actors. If regenerative science is not a politicized (in the sense of value-laden) science, it is a science that politicizes the issues it studies. This creates the potential for a more symbiotic relationship between science and democracy.

Regenerative science can play three different roles in this process of democratic decision-making. First, scientists can act as *spokespersons* for humans and non-humans. By carefully describing reality, regenerative research can give voice to the voiceless, bringing unnoticed problems or disregarded issues to the political agenda. Second, science can *broaden policy-makers' imagination* by providing comparative knowledge and a menu of options available to deal with a specified issue, or by inventing new solutions to existing problems. Third, scientific research can guide the political decision-making by *assessing the likely consequences of different policies*, visualizing the multiplicity of possible future that we have to collectively decide to pursue or avoid. Because these models and simulations are understood as mere simplifications of reality, not reality itself, they can only serve as guides for decision-making (see Latour, 2004).

"Listen to the science" should thus not be understood as "obey the scientists", but rather: "hear their warnings," "consider the solutions they propose," and "use their assessments as guides". Scientists are no longer above the political debate. Their voice is one voice amongst others (Stengers, 2018). But as we enter a period of great instability and uncertainty, this voice is perhaps more needed than ever in the broader debate about the future we decide to create in common.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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6 Such efforts have been pursued in fields such philosophy (Charbonnier, 2021), international relations (Yao, 2022), international law (Natarajan and Khoday, 2014), political science (Mitchell, 2011) or agriculture (Kazic, 2019).

7 While the focus is here placed on academic research, the same issues are also pressing—indeed perhaps more pressing—for research conducted *outside* of academia (e.g., in think-tanks or in the military).

References

Ake, C. (1982). *Social Science as Imperialism: The Theory of Political Development*. Ibadan: Ibadan University Press.

Antonelli, A. (2023). Indigenous knowledge is key to sustainable food systems. *Nature* 613, 239–242. doi: 10.1038/d41586-023-00021-4

Bauman, Z. (1989). *Modernity and the Holocaust*. Cambridge: Polity.

Bender, E. M., Gebru, T., McMillan-Major, A., and Shmitchell, S. (2021). "On the dangers of stochastic parrots: can language models be too big?", in *FAcct'21: Proceedings of the* (2021). *ACM Conference on Fairness,*

Accountability, and Transparency. New York, NY: The Association for Computing Machinery.

Bennett, J. (2010). *Vibrant Matter: A Political Ecology of Things*. Durham: Duke University Press.

Bergson, H. (2023). *Creative Evolution*. New York, NY: Routledge.

Best, S. (1991). Chaos and entropy: metaphors in postmodern science and social theory. *Sci. Cult.* 2, 188–226. doi: 10.1080/09505439109526302

Blanco-Wells, G. (2021). Ecologies of repair: a post-human approach to other-than-human natures. *Front. Psychol.* 12, 633737. doi: 10.3389/fpsyg.2021.633737

Bowden, B. (2009). *The Empire of Civilization*. Chicago, IL: University of Chicago Press.

Braidotti, R. (2019). *Posthuman Knowledge*. Vol. 2. Cambridge, MA: Polity Press.

Carson, R. (1962). *Silent Spring*. Boston, MA: Houghton Mifflin

Cartwright, N. (1984). *How the Laws of Physics Lie*. Oxford: Oxford University Press.

Charbonnier, P. (2021). *Affluence and Freedom: An Environmental History of Political Ideas*. Medford, OR: Polity Press.

Chilisa, B. (2007). Responsible research ethics in African contexts. *Mosenodi* 15, 17–13.

Chilisa, B. (2019). *Indigenous Research Methodologies*. Thousan Oaks, CA: Sage Publications.

de Sousa Santos, B. (2015). *Epistemologies of the South: Justice Against Epistemicide*. New York, NY: Routledge.

DeLanda, M. (2015). The new materiality. *Architect. Design* 85, 16–21. doi: 10.1002/ad.1948

Deleuze, G., and Guattari, F. (1987). *A Thousand Plateaus*. London; New York, NY: Continuum.

Epstein, S. (1996). *Impure Science: AIDS, Activism, and the Politics of Knowledge*. Berkeley: University of California Press.

Escobar, A. (2016). Thinking-feeling with the earth: territorial struggles and the ontological dimension of the epistemologies of the South. *Revista de Antropología Iberoamericana* 11, 11–32. doi: 10.11156/aibr.110102e

Finlayson, A. C. (1994). *Fishing for Truth: A Sociological Analysis of Northern Cod Stock Assessments from 1977 to 1990*. St. John's, NL: Institute of Social and Economic Research.

Fornstedt, H. (2021). *Innovation resistance: moving beyond dominant framings* (PhD Dissertation), Faculty of Science and Technology, Uppsala University, Uppsala, Sweden.

Gaard, G. (2001). Women, water, energy: an ecofeminist approach. *Org. Environ.* 14, 157–172. doi: 10.1177/1086026601142002

Gardner, C. J., Thierry, A., Rowlandson, W., and Steinberger, J. K. (2021). From publications to public actions: the role of universities in facilitating academic advocacy and activism in the climate and ecological emergency. *Front. Sustain.* 2, 42. doi: 10.3389/frsus.2021.679019

Gare, A. (2022). "Creating the future," in *The Palgrave Encyclopedia of the Possible*, eds V. Petre Glăveanu (Cham: Springer), 1–9.

Garlick, J. A., and Levine, P. (2017). Where civics meets science: building science for the public good through civic science. *Oral Dis.* 23, 692–696. doi: 10.1111/odi.12534

Gasper, R., Blohm, A., and Ruthm, M. (2011). Social and economic impacts of climate change on the urban environment. *Curr. Opin. Environ. Sustain.* 3, 150–157. doi: 10.1016/j.cosust.2010.12.009

Godin, B. (2015). *Innovation Contested: The Idea of Innovation Over the Centuries*. New York, NY: Routledge.

Grenoble, L. A., and Whaley, L. J. (2021). Toward a new conceptualisation of language revitalisation. *J. Multiling. Multicult. Dev.* 42, 911–926. doi: 10.1080/01434632.2020.1827645

Gustafsson, B., Ryden, L., Tibell, G., and Wallensteen, P. (2021). "The Uppsala code of ethics for scientists," in *Peter Wallensteen: A Pioneer in Making Peace Researchable*, ed P. Wallensteen (Cham: Springer), 105–112.

Hamilton, C. (2013). *Earthmasters: The Dawn of the Age of Climate Engineering*. Yale, MI: Yale University Press.

Hamilton, C. (2016). The theodicy of the "Good anthropocene". *Environ. Human.* 7, 233–238. doi: 10.1215/22011919-3616434

Haraway, D. J. (1988). Situated knowledges: the Sscience question in feminism and the priviledge of partial perspective. *Feminist Stud.* 14, 575–599. doi: 10.2307/3178066

Hardin, G. (1985). Human ecology: the subversive, conservative science. *Am. Zool.* 25, 469–476. doi: 10.1093/icb/25.2.469

Harding, S. G. (1986). *The Science Question in Feminism*. Cornell: Cornell University Press.

Harman, G. (2018). *Object-Oriented Ontology: A New Theory of Everything*. London: Pelican Books.

Herman, D., and Cobb, J. (1994). *For the Common Good: Redirecting the Economy toward Community, the Environment, and a Sustainable Future*. Boston: Beacon Press.

Higgs, E. (2003). *Nature by Design: People, Natural Process, and Ecological Restoration*. Cambridge: MIT Press.

Higuchi, T. (2020). *Political Fallout: Nuclear Weapons Testing and the Making of a Global Environmental Crisis*. Stanford, CA: Stanford University Press.

Hodgson, G. M. (2002). Darwinism in economics: from analogy to ontology. *J. Evolut. Econ.* 12, 259–281. doi: 10.1007/s00191-002-0118-8

Hulme, M. (2011). Reducing the future to climate: a story of climate determinism and reductionism. *Osiris* 26, 245–266. doi: 10.1086/661274

Ide, T., Johnson, M. F., Barnett, J., Krampe, F., Le Billon, P., Maertens, L., et al. (2023). The future of environmental peace and conflict research. *Environ. Polit.* (pre-print) 1–27. doi: 10.1080/09644016.2022.2156174

IPCC (2021). *Sixth Assessment Report*. Geneva: Intergovernmental Panel on Climate Change.

Jackson, S. T., and Hobbs, R. J. (2009). Ecological restoration in the light of ecological history. *Science* 325, 567–569. doi: 10.1126/science.1172977

Jahn, B. (1999). IR and the state of nature: the cultural origins of a ruling ideology. *Rev. Int. Stud.* 25, 411–434. doi: 10.1017/S0260210599004118

Janot, P., and Blondel, A. (2022). The carbon footprint of proposed e+e- Higgs factories. *Eur. Phys. J. Plus* 137, 1–8. doi: 10.1140/epjp/s13360-022-03319-w

Jundt, T. (2014). Dueling visions for the postwar world: the un and unesco 1949 conferences on resources and nature, and the origins of environmentalism. *J. Am. Hist.* 101, 44–70. doi: 10.1093/jahist/jau246

Kazic, D. (2019). *Plantes animées. De la production aux relations avec les plantes* (PhD Dissertation). École doctorale Agriculture, alimentation, biologie, environnement, santé, Université Paris-Saclay, Gif-sur-Yvette, France

Keen, S. (2021). The appallingly bad neoclassical economics of climate change. *Globalizations* 18, 1149–1177. doi: 10.1080/14747731.2020.1807856

Kimmerer, R. W. (2011). "Restoration and reciprocity: the contributions of traditional ecological knowledge," in *Human Dimensions of Ecological Restoration: Integrating Science, Nature, and Culture, edited by Dave Egan,* eds E. E. Hjerpe and J. Abrams (Washington, DC: Island Press).

Kimmerer, R. W. (2013a). *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants*. Minneapolis, MN: Milkweed Editions.

Kimmerer, R. W. (2013b). "The fortress, the river and the garden: a new metaphor for cultivating mutualistic relationship between scientific and traditional ecological knowledge," in *Contemporary Studies in Environmental and Indigenous Pedagogies*, eds A. Kulnieks, D. R. Longboat, and Y. Young (Rotterdam: Sense), 49–76.

Krause, S. R. (2020). Environmental domination. *Polit. Theory* 48, 443–468. doi: 10.1177/0090591719890833

Krimsky, S. (2004). *Science in the Private Interest: Has the Lure of Profits Corrupted Biomedical Research?* Lanham: Rowman and Littlefield.

Latour, B. (1993). *We Have Never Been Modern*. Cambridge, MA: Harvard University Press.

Latour, B. (2004). *Politics of Nature: How to Bring the Sciences Into Democracy*. Cambridge, MA: Harvard University Press.

Latour, B. (2007). *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford: Oxford University Press.

Latour, B. (2017). *Facing Gaia: Eight Lectures on the New Climatic Regime*. Cambridge, MA: Polity.

Leopold, A. (1987). *A Sand County Almanac*. New York, NY; Oxford: Oxford University Press.

Lidskog, R., Sundqvist, G., Kall, A. S., Sandin, P., and Larsson, S. (2013). Intensive forestry in Sweden: stakeholders' evaluation of benefits and risk. *J. Integr. Environ. Sci.* 10, 145–160. doi: 10.1080/1943815X.2013.841261

Littman, J. A. (2009). *Regenerative architecture: a pathway beyond sustainability* (Master thesis). Department of Art, Architecture and Art History, University of Massachusetts, Amherst, MA, United States.

Longino, H. E. (1990/2020). *Science as Social Knowledge*. Princeton: Princeton University Press.

Malm, A. (2016). *Fossil Capital: The Rise of Steam Power and the Roots of Global Warming*. London: Verso Books.

Malm, A., and Hornborg, A. (2014). The geology of mankind? A critique of the Anthropocene narrative. *Anthropocene Rev.* 1, 62–69. doi: 10.1177/2053019613516291

Malmuth, A. (2021). *The Earth Is Doing Our Thinking for Us: A Conversation with Amitav Ghosh. Los Angeles Review of Books* (2021). Available online at: https://lareviewofbooks.org/article/the-earth-is-doing-our-thinking-for-us-a-conversation-with-amitav-ghosh/ (accessed March 1, 2023).

Maran, T. (2020). *Ecosemiotics: The Study of Signs in Changing Ecologies*. Cambridge, MA: Cambridge University Press.

Martínez, F. (2017). Waste is not the end. For an anthropology of care, maintenance and repair. *Soc. Anthropol.* 25, 346–350. doi: 10.1111/1469-8676.12436

McDonough, W., and Braungart, M. (2002). *Cradle to Cradle: Remaking the Way We Make Things*. New York, NY: North Point Press.

Merchant, C. (1980). *The Death of Nature: Women, Ecology, and the Scientific Revolution*. San Fransisco, CA: Harper Collins.

Merleau-Ponty, M. (2013). *Phenomenology of Perception*. New York, NY: Routledge.

Mertens, D. M. (2008). *Transformative Research and Evaluation*. New York, NY: Guilford Press.

Micklos, D., and Carlson, E. (2000). Engineering American society: the lesson of eugenics. *Nat. Rev. Genet.* 1, 153–158. doi: 10.1038/35038589

Mirin, A. A. (2021). Gender disparity in the funding of diseases by the US National Institutes of Health. *J. Womens Health* 30, 956–963. doi: 10.1089/jwh.2020.8682

Mitchell, T. (2011). *Carbon Democracy. Political Power in the Age of Oil*. London: Verso.

Morcol, G. (2001). What is complexity science? Postmodernist or psotpositivist? Emergence. *J. Compl. Issues Org. Manag.* 3, 104–119. doi: 10.1207/S15327000EM0301_07

Muir, W. M., and Howard, R. D. (1999). Possible ecological risks of transgenic organism release when transgenes affect mating success: sexual selection and the Trojan gene hypothesis. *Proc. Natl. Acad. Sci.* 96, 13853–13856. doi: 10.1073/pnas.96.24.13853

Natarajan, U., and Khoday, K. (2014). Locating nature: making and unmaking international law. *Leiden J. Int. Law* 27, 573–593. doi: 10.1017/S0922156514000211

Nevins, J. (2014). Academic jet-setting in a time of climate destabilization: ecological privilege and professional geographic travel. *Prof. Geogr.* 66, 298–310. doi: 10.1080/00330124.2013.784954

Norgaard, R. B. (2010). Ecosystem services: from eye-opening metaphor to complexity blinder. *Ecol. Econ.* 69, 1219–1227. doi: 10.1016/j.ecolecon.2009.11.009

Oreskes, N. (2021). *Why Trust Science?* Princeton: Princeton University Press.

Oreskes, N., and Conway, E. M. (2010). Defeating the merchants of doubt. *Nature* 465, 686–687. doi: 10.1038/465686a

Oreskes, N., and Conway, E. M. (2015). *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. New York, NY: Bloomsbury Press.

Otto, F. E., Harrington, L., Schmitt, K., Philip, S., Kew, S., and van Oldenborgh, G. J. (2020). Challenges to understanding extreme weather changes in lower income countries. *Bull. Am. Meteorol. Soc.* 101, 1851–1860. doi: 10.1175/BAMS-D-19-0317.1

Pamuk, Z. (2021). *Politics and Expertise: How to Use Science in a Democratic Society*. Princeton: Princeton University Press.

Prigogine, I., and Stengers, I. (2018). *Order Out of Chaos: Man's New Dialogue with Nature*. London: Verso Books.

Raworth, K. (2017). *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*. London: Random House.

Rhodes, C. J. (2017). The imperative for regenerative agriculture. *Sci. Prog.* 100, 80–129. doi: 10.3184/003685017X14876775256165

Rovelli, C. (2021). Politics should listen to science, not hide behind it. *Nat. Mat.* 20, 272–272. doi: 10.1038/s41563-020-00891-3

Schmutz, S., and Moog, O. (2018). "Dams: ecological impacts and management," in *Riverine Ecosystem Management: Science for Governing Towards a Sustainable Future*, eds. S. Schmutz and J. Sendzimir (Cham: Springer), 111–127.

Silvertown, J. (2009). A new dawn for citizen science. *Trends Ecol. Evol.* 24, 467–471. doi: 10.1016/j.tree.2009.03.017

Smith, L. T. (2021). *Decolonizing Methodologies: Research and Indigenous Peoples*. New York, NY: Bloomsbury Publishing.

Sörlin, S. (2012). Environmental humanities: why should biologists interested in the environment take the humanities seriously? *BioScience* 62, 788–789. doi: 10.1525/bio.2012.62.9.2

Srinivasan, A. (2015). Stop the robot apocalypse: the new utilitarians. *London Rev. Books* 37, 3–6.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., and Bennett, E. M. (2015). Planetary boundaries: guiding human development on a changing planet. *Science* 347, 1259855. doi: 10.1126/science.1259855

Stengers, I. (2018). *Another Science is Possible: A Manifesto for Slow Science*. New York, NY: Polity.

Sultana, F. (2022). The unbearable heaviness of climate coloniality. *Polit. Geogr.* 99, 102638. doi: 10.1016/j.polgeo.2022.102638

Swyngedouw, E. (2013). The non-political politics of climate change. *ACME Int. J. Crit. Geogr.* 12, 1–8.

Thompson, E. L., and Smith, L. A. (2019). Escape from model-land. *Economics* 13, 1–15. doi: 10.5018/economics-ejournal.ja.2019-40

Todd, N. J., and Todd, J. (1994). *From Eco-cities to Living Machines: Principles of Ecological Design*. Berkeley, CA: North Atlantic Books.

UK Government Office for Science (2007). *Rigour, Respect, Responsibility. A Universal Ethical Code for Scientists*. Department for Innovation, Universities, and Skills. Available online at: https://www.gov.uk/government/publications/universal-ethical-code-for-scientists (accessed March 1, 2023).

Van Der Ryn, S., and Cowan, S. (1996). *Ecological Design*. Washington, DC: Island Press.

Warde, P., Robin, L., and Sörlin, S. (2018). *The Environment: A History of the Idea*. Baltimore, MD: John Hopkins University Press.

Whitehead, A. N. (1987). *Process and Reality*. New York, NY: The Free Press.

Wynne, B. (1996). "May the sheep safely graze? A reflexive view of the expert-lay knowledge divide," in *Risk, Environment and Modernity: Towards a New Ecology*, eds S. Lash, B. Szerszynski, and B. Wynne (New York, NY: Sage).

Yao, J. (2022). *The Ideal River: How Control of Nature Shaped the International Order*. Manchester: Manchester University Press.

Zalasiewicz, J., Williams, M., Steffen, W., and Crutzen, P. (2010). The new world of the Anthropocene. *Environ. Sci. Technol.* 44, 2228–2231. doi: 10.1021/es903118j