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Communicating about soil biodiversity: Insights from science editorials and future recommendations

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ABSTRACT

Given the urgency of the global soil degradation crisis, soil scientists must communicate the importance of soil as being part of nature and the critical need for conserving soil biodiversity. Drawing on a thematic analysis of editorials related to soil conservation and management, we analyzed common themes, key messages, and frames that authors used to advocate for change. Soil biodiversity was referred to in 8 of the 11 editorials, but it was less emphasized and discussed in less detail than messages centered around food production, water resources, and climate change. Editorials structured arguments around economic development, scientific and technical uncertainty, and morality and ethics. We believe future editorials should apply other persuasive frames including social progress, public accountability, and working-towards-compromise when advocating for soil biodiversity conservation. Soil ecologists can improve communications about soil biodiversity by (1) identifying an audience and selecting relevant key messages, (2) strategically applying a persuasive frame, and (3) amplifying diverse voices with a consistent message. We provide a guide for developing essays that encourages soil ecologists to shape discourse, advance policy priorities, and enable non-soil ecologists to communicate about soil biodiversity conservation.

Soils harbor significant biodiversity with innumerable organisms that interact in complex communities from which critical ecosystem processes emerge (Orgiazzi et al., 2016; Nielsen et al., 2015). Despite this, soils are degrading at an alarming rate globally with persistent threats to soil biodiversity (Orgiazzi et al., 2016; Amundson et al., 2015). Soil scientists face challenges like those in climate change discourse when communicating about global soil degradation: the public lacks a nuanced understanding of the problem; it is difficult to translate awareness to action and behavioral change; and the broad scope of the problems (and solutions) may lead to feelings of being overwhelmed and hopeless (Moser, 2016). Addressing these challenges requires diverse science communication strategies that identify soils as a "keystone" to solving global environmental challenges (Bouma and McBratney, 2013), and articulate the "essence" of soil biodiversity (Byrne, 2022). To increase public appreciation of soil biodiversity and garner support for conservation research and policies, soil biologists and ecologists (hereafter soil ecologists for simplicity) should employ diverse rhetorical strategies informed by science communication research. When soil ecologists align communication strategies within the discipline, the argument for soil biodiversity conservation becomes more compelling to non-soil scientists who can then advocate for the same goals.

Science editorials are one form of science communication that can inform rhetorical strategies by both critiquing how science is disseminated and offering recommendations (Hulme et al., 2018). Editorials are texts grounded in persuasive frames and reveal the rhetorical devices used by scientists to communicate ideas and advocate for change. These are defined as "openly subjective and highly opinionated, taking strong stands on issues of interest" (Sommer and Maycroft, 2008, p. 588). Hence, editorial essays are an opportunity for soil ecologists to appeal to their colleagues about the need to study, preserve, and advocate for soil biodiversity. Scientists in related disciplines (e.g., Earth science, plant science, ecology, geology, conservation biology) can draw from the key messages and frames presented in editorials when communicating about soils, their biodiversity, and associated topics. Similarly, these communication strategies may then be picked up by non-scientists (e.g. journalists, land managers, conservation advocates) who increasingly communicate about soil life. In short, consistency in messaging enables

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amplification and persuasion (Williams and Eosco, 2021; Soares et al., 2023).

While some soil ecologists have appealed broadly to other scientists in academic journals through editorials, we argue that even more can be done by learning from the communication strategies used by climate scientists, whose prolific and diverse ways of communicating to different audiences have ensured that both academics and non-academics engage in discussions about the importance of climate change (Leiserowitz et al., 2021). For example, over a 50-year period, there were 500 editorials in just two academic journals (*Science* and *Nature*) that focused on climate change and the engagement of scientists with the public (Hulme et al., 2018). Likewise, soil ecologists can engage the broader scientific community in discussions about the importance of including soil biodiversity in public dialogue about conservation. Furthermore, it behooves soil ecologists to use rhetorical devices, such as framing, to appeal to a broader audience. Here, we examine how soil scientists have incorporated soil biodiversity into their own editorial essays in academic journals.

Using thematic analytical methods (Braun and Clarke, 2006) to identify rhetorical strategies, we examined: 1) how many soil-related editorials were published over 21 years in 17 academic journals; 2) common themes and key messages in the editorials and 3) rhetorical devices (i.e., framing) authors used to advocate for change (see Supplementary Materials for methods). We conducted our search in both disciplinary-specific journals (e.g., *Soil Biology and Biochemistry*) and journals with a broader science audience (e.g., *Nature*). We selected editorials that discussed soil management, conservation, and/or restoration through a general lens, rather than describing a specific technique or finding. Several insights emerged. First, unlike climate change, a topic about which science editorials are plentiful (e.g., Hulme et al., 2018), we retrieved only 11 editorials over 21 years in the academic journals surveyed (Supplementary Materials). Second, while biodiversity and soil life were described in several editorials (8 of 11), this theme was less common compared to arguments focusing on food production (11 of 11) and security (11 of 11), water resources (9 of 11), and climate change (9 of 11) (Supplementary Materials). In other words, soil ecology was more often presented in the context of anthropocentric concerns and ecosystem services rather than through the lens of biodiversity conservation. Third, editorial authors most commonly framed their arguments around economic development, scientific and technical uncertainty, and morality and ethics (Nisbet, 2014), but other rhetorical devices may be useful for communicating about soil biodiversity. Below, we unpack the common themes, key messages, and rhetorical devices that recurred in the editorials and provide recommendations for future communication about soil biodiversity.

1. Common themes and key messages

Prioritizing the expertise of soil scholars and practitioners can lead to greater integration of soil knowledge in decision making (Gonzalez Lago et al., 2019). To do so, soil scientists should identify critical ideas to align messaging and provide guidance for those outside the discipline to amplify these messages. For example, the key messages put forth by the Food and Agriculture Organization of the United Nations (FAO) during the 2015 International Year of Soils (Supplementary Materials) and for annual World Soil Day campaigns provide broad guidance for those developing arguments about the importance of soil. These messages include production and security of food, fuel, and fiber, water resources, climate change, and biodiversity. The messaging around links between soil and biodiversity highlights that soils both support biodiversity aboveground and serve as habitat for biodiversity belowground. Our analysis of editorials revealed that FAO key messages are well aligned with the ideas and priorities of soil scientists (Supplementary Materials). Broad key messages can be particularly useful for non-scientists communicating about soils and related environmental issues, so soil scientists should continue aligning their messages with those of the FAO. However, general soil knowledge may be communicated without direct consideration of soil biodiversity. Soil ecologists have expertise and ideas that go far beyond general messages about soil conservation. Even when soil ecologists acknowledge the important role that biota play in soil functions, it is important to communicate these ideas within the broader scientific discipline and public. Key messages about soil life are needed to raise awareness about its importance among scientists, in formal educational settings, and in public discouse.

We posit that general messages about soil conservation should be coupled with more specific messages when communicating about a component of soils such as soil life. Specific key messages can help soil ecologists and disciplinary allies communicate about and advocate for soil biodiversity more effectively. The Global Soil Biodiversity Atlas identifies seven key messages specific to the conservation of soil life including the importance of the soil as habitat, identifying patterns of soil biodiversity around the globe, connecting soil biodiversity with specific ecosystem services, threats to soil biodiversity, and prioritizing policy solutions (Orgiazzi et al., 2016). The editorials we reviewed echo these messages. For example, Manter et al., 2017 identify soil as habitat and call for a global repository to help identify spatial patterns of soil biodiversity and functions. Editorials also linked soil biodiversity to ecosystem services such as supporting human health (Wall and Six, 2015) and ecological processes such as bioweathering (Banwart, 2011). Some editorials identified threats to soil biodiversity from human activities such as land use change (Anonymous, 2010) and proposed policy solutions (Wall and Six, 2015). Even so, soil biodiversity was not a major thematic emphasis in the editorials we reviewed.

The concept of soil health provides an example of the implications of a lag in communications about soil life among scientists. Soil health is generally useful as a metaphor to guide discussion about soil functions, despite challenges of definition, measurement, and interpretation (Lehmann et al., 2020; Janzen et al., 2021). Even though we understand that biological interactions support soil health, efforts to quantify soil health still primarily rely on chemical indicators (Lehmann et al., 2020). Only one of the editorials(Manter et al., 2017) made the link between soil biota and soil health explicit, while the three other editorials that mention soil health provided either general descriptions or defined the concept based on soil functions (Grandy et al., 2010; Anonymous 2015b; Anonymous, 2017). As a result, policy initiatives underpinned by the soil health concept may lack meaningful integration with soil biota.

Soil ecologists can use key messages about soil biodiversity to guide public discourse and subsequently policy priorities. However, scientific messages with many dimensions of complexity, such as those about soil biodiversity conservation, may not be readily translated into public discourse, practice, and policy (Meinard and Quétier, 2014). In fact, a review of conservation policies in Europe found limited benefits of those policies for soil biodiversity (Zeiss et al., 2022). In addition to aligning key messages, another way to address the challenges of communicating complexity is to use similar, consistent persuasive perspectives ("frames") so that scholars whose interests intersect with soil ecologists' can evaluate which ideas to prioritize.

2. Frames used in essays about soil biodiversity

Soil ecologists can use framing to highlight values and morals, create a shared sense of reality, and persuade diverse audiences about important issues (Druckman, 2001; Goffman, 1974). By applying a frame when presenting an argument, a communicator can persuade their audience about the importance of an issue (Hulme et al., 2018). When writing about science, people communicate messages through the lens of their own perspectives, beliefs, and expertise (Balgopal et al., 2017; Kelly and Takao, 2003). They draw on data to support their positions based on both what is meaningful to them and what they perceive their audience will understand (Nielsen, 2011). The process of framing leads scientists to interpret scientific issues for readers in non-neutral ways, even if they intend to remain objective (Weber and Schell Word, 2001).

Acknowledging this dimension of communication and strategically selecting an appropriate frame will help soil ecologists better simplify and convey their messages to diverse audiences. In other words, message consistency helps audiences remember take-home points (Williams and Eosco, 2021).

Nisbet's (2014) typology of frames used in science writing illustrates the most common ways that science essays are presented including: (1) social progress; (ii) economic development; (iii) morality and ethics; (iv) scientific and technical uncertainty; (v) awareness of 'runaway' science; (vi) public accountability; (vi) working-towards-compromise; and (viii) conflict and strategy among competing science writers. This typology can be applied beyond written arguments and serves as a heuristic to strengthen and align communication around soil biodiversity. Our survey of editorials revealed that soil scientists already apply frames that align with Nisbet's (2014) framework, whether intentionally or not. The economic development, scientific and technical uncertainty, and morality and ethics frames were most commonly applied in the editorials we reviewed.

Centering the economic value of soils and their functions may be key to attracting the attention and action of policy makers (Dazzi and Lo Papa, 2022). In our sample of soil-related editorials, the economic development frame was prevalent. Authors called for action through political (4 of 11 editorials) and financial (5 of 11) investments in soil management and conservation (Supplementary Materials). For example, in the essay *A Business Case for Soil,* Davies (2017) applies the economic development frame by arguing for investment in soil remediation from business leaders to mitigate risks of environmental crises to supply chains. Investing in and incentivizing advanced technology to improve soil management is also proposed as a solution to soil degradation by Grandy et al. (2010). Soil biodiversity provides both output values (ecosystem services) and insurance values (mitigating and adapting to risks) as natural capital (Pascual et al., 2015). Greater accessibility to soil information that describes the economic value of soil biodiversity and its contributions to sustainability goals can lead to stronger policies that aid soil stewardship (Bach et al., 2020). The policies themselves also serve to communicate soil issues to the public (Bouma et al., 2012). Increasing the translation of soil biodiversity science into economic and policy decisions requires that soil science and ecology experts first engage in dialogue within the scientific community so that messages can be clearly translated to actions. For example, Wall & Six (2015) highlighted examples of successful engagement with policy makers to direct initiatives aimed at conserving soils and biodiversity. Successful narratives around soil issues must consider not only robust scientific findings, but also integrate socio-political dimensions (Bouma, 2015; Gonzalez Lago et al., 2019), as done by several editorial authors: Wall and Six (2015), Banwart (2011), and Montanarella (2015).

Much scientific and technical uncertainty surrounding soil biodiversity still exists as soil biodiversity is understudied compared to other domains of biodiversity (Guerra et al., 2022; Orgiazzi et al., 2016). Arguments to conserve soil biodiversity benefit from framing around uncertainty (Guerra et al., 2022), particularly when evaluating risks of biodiversity loss due to anthropogenic influences (Pascual et al., 2015) and designing conservation strategies (Parker, 2010). Editorial authors commonly drew on this frame. For example, the essay *Investing in Soils* (Anonymous, 2010) ends by identifying an urgent need to know more about how soils respond to climate and land use changes. Yaalon (2000) argues for greater investment in research of pedodiversity and biodiversity to fill knowledge gaps that are relevant for understanding human-environment interactions. Similarly, another editorial (Anonymous, 2015) argues that understanding the soil environment is the first step to soil conservation. However, this one did not explicitly identify soil biodiversity as a component of the soil environment, underscoring the need to better integrate soil life into dialogue about soil conservation (Guerra et al., 2021). In terms of technological uncertainty, Manter et al., (2017) argue that soil preservation is necessary because technology to characterize soil biological communities continues to advance rapidly.

When advocating for preserving soil biodiversity and engaging in soil stewardship, arguments that frame soils in the context of morality and ethics (Nisbet, 2014) are needed. There was some mention of soil stewardship in two of the editorials (Anonymous, 2015b, Grandy et al., 2010). However, none of them explicitly mention a moral obligation to conserve soils or soil biodiversity. Caring for soils requires a relational view of soils and their inhabitants as entities that are intrinsically valued (Puig De La Bellacasa, 2015; Krzywoszynska, 2019). Yaalon (2000) described the inherent value of soils as a part of nature and Grandy et al. (2010) mention needing to "care for" soils, but none of the editorials explicitly framed their argument around the concept of soil care (*sensu* Puig De La Bellacasa, 2015). We suggest that soil ecologists consider persuasive frames that make a moral argument for preserving soil biodiversity for its own sake, rather than conceptualizing soil as a natural resource from which humanity can extract economic value. One way to advance this message is by focusing on cultivating curiosity in a variety of audiences for the complex, often unseen ecological interactions between soil organisms (Byrne, 2022).

3. Recommendations for communicating about soil biodiversity

We encourage soil ecologists and communicators to (1) clearly identify their audience and select key messages accordingly, (2) strategically communicate arguments using a persuasive frame, such as one of Nisbet's (Box 1), and (3) amplify diverse perspectives while communicating consistently about the importance of soil biodiversity.

3.1. Identify audience and select relevant key messages

Communication efforts aimed at specific audiences and contexts may necessitate different or multiple key messages. Identifying relevant themes can reveal the motivations behind arguments to make them stronger. While individual communicators may focus on a single message or audience, soil ecologists as a collective group of communicators should consider the multiple key messages and persuasive strategies discussed above that are best suited for the audience and context (Gonzalez Lago et al., 2019). Both the quality and quantity of arguments included in a communication effort influence its effectiveness. In doing so, claims can be more persuasive (Petty and Cacioppo, 1984; Ranganath et al., 2010).

Soil ecologists can shape discourse about soil biodiversity by carefully considering the audiences with whom they already communicate. Both students and the public can help spread awareness of soil biodiversity and translate ideas to actions, but they rely on clear, aligned messaging from experts. Soil ecologists who teach courses on relevant topics can influence how students in their classes communicate about soils beyond the classroom by modeling an approach that emphasizes curiosity and action (e.g., soil care and stewardship). Formal soil science education may benefit from moving away from a sub-disciplinary organization toward a more integrated approach based on soil functions, services, and health (Brevik et al., 2022). Discussions of soil biodiversity fit well within these integrated approaches because soil organisms mediate many soil functions and are an inherent component of soil health (Lehmann et al., 2020). Yet, a survey of focal topics in undergraduate soil science courses in the US revealed that biological properties were not included in the top 10 most deeply taught topics (Jelinski et al., 2019). This "soil education gap" wherein soil biodiversity is underemphasized in soil science courses must be addressed (Byrne, 2016; Eisenhauer et al., 2022), but knowledge of soil does not necessarily translate to soil stewardship (Neaman et al., 2024). Soil ecologists engaged in education should identify key messages related to soil biodiversity that are contextualized and relevant to the student population so that greater soil literacy will transcend the "soil stewardship paradox" (Neaman et al., 2024) and inform the way students regard, speak about, and interact with soils and soil life.

Box 1
Guide to preparing essays about soil biodiversity.

Soil ecologists can apply Nisbet (2014)'s persuasive frames to essays advocating for soil biodiversity conservation. These guiding questions are aimed to spark ideas for editorials, perspectives, and opinion pieces in academic journals and news outlets that facilitate discourse and shape ideas.

Understanding Your Audience

- Who is your audience?
- Which key messages are most relevant to your audience?
- Which frame would your audience find most convincing?

Economic Development Frame

- What economic value does soil biodiversity provide?
- What are the economic consequences of a loss of soil biodiversity?

Scientific and Technological Uncertainty Frame

- What aspects of soil biodiversity are soil ecologists still uncertain about?
- How does/can/should uncertainty about soil biodiversity inform conservation policies?

Morality and Ethics

- What is our moral obligation to conserve soil biodiversity?
- Why do we have an ethical responsibility towards soil organisms?

Social Progress

- How will learning more about soil biodiversity improve people's lives?
- How can soil management and restoration facilitate human health and wellbeing?

Working-Towards-Compromise

- What is the role of collaboration in soil biodiversity conservation?
- Who should be involved and what are areas of potential compromise?

Public Accountability

- Who is accountable for conserving soil biodiversity?
- What measures can be taken to ensure accountability to responsible parties?

It is critical to ground communication efforts in local contexts and communities because our perception of biodiversity depends on context (Cicchino et al., 2023; Bernardo et al., 2021). When people experience public communications that value biodiversity in their community, they are more likely to perceive biodiversity as important (Bernardo et al., 2021). Communications that ground global issues in local soil features, processes, and challenges can connect directly with a local audience and lead to greater soil stewardship (Fairhead and Scoones, 2005). For example, in an urban setting, discussions about soil degradation could focus on novel anthropogenic soil types, patterns of urban soil biodiversity, challenges with trace metal contamination, and opportunities for soil restoration (Byrne and Szlavecz, 2023; Paltseva et al., 2022; Kim et al., 2014). Localizing communications is especially needed for soil biodiversity where species are geographically restricted (Byrne, 2022) and therefore valued differently depending on location, time, and stakeholder perspectives. To engage public audiences in discourse about local soils, soil ecologists can increase awareness and appreciation through soil art and aesthetics (Moscatelli and Marinari, 2024; MacEwan et al., 2017; Feller et al., 2015), by framing messages around terroir, soil health, and soil security (Brevik et al., 2019), and by expanding accessibility to local soil knowledge through atlases and databases (Bouma et al., 2012; Orgiazzi et al., 2016). In all cases, careful consideration of the themes and messages that resonate with an audience will increase the impact of communication efforts.

3.2. *Strategically apply a persuasive frame*

Depending on the audience and intended message, soil ecologists can use several persuasive frames to craft narratives about soil biodiversity (Box 1). In addition to the frames commonly used in the editorials presented aboved, soil ecologists can also apply the social progress, working-towards-compromise, and public accountability frames (Nisbet, 2014). The social progress frame (Nisbet, 2014) argues that greater understanding about soil biodiversity will improve people's lives. This frame is appropriate because soil scientists have identified links between soil biodiversity, soil functions, and human health (Wall et al., 2015; Brevik et al., 2020). Communities also need access to information about the connections between soils and human health to make decisions at individual and organizational scales (Brevik et al., 2020).

Soil degradation is a "wicked problem" that requires coordination across many areas of expertise and lived experience. Most of the editorials in our analysis (10 of 11) included more than one call-to-action, suggesting agreement among authors that addressing soil degradation requires multiple interacting solutions. To this end, soil scientists must engage across networks of land users, regulators, and scientists to expand attention to and care for soils and their inhabitants (Krzywoszynska, 2019). Six of the editorials called for greater collaboration among scientists, land managers, and policy makers (Supplementary Materials), but collaboration does not necessarily imply compromise. Framing the problem as complex and multifaceted is a critical first step to environmental governance where consensus building can be challenging when those involved have diverse and sometimes divergent interests (van den Ende et al., 2023). The working-towards-compromise frame (Nisbet, 2014) can be used to acknowledge that diverse communities of practice will have different ideas about soil biodiversity conservation. Similarly, the public accountability frame (Nisbet, 2014) can be applied to advocate for collective action by exploring who is responsible for following through on conservation goals related to soils. Such dialogue can lead to "responsibilization" (*sensu* van den Ende et al., 2023) of the soil degradation crisis.

3.3. Amplify diverse voices with a consistent message

Our review found that soil biodiversity was not a major emphasis in editorials arguing for soil conservation. Consistent messaging about the role of soil biodiversity in ecosystems and the need for conservation is critical (Williams et al., 2021). But consistent key messages alone are not enough. Soil ecologists must also communicate those messages persuasively. We found that several persuasive frames are underutilized in editorials. Communicators select different persuasive frames based on their lived experience and cultural context (Balgopal et al., 2017). To make soil conservation an issue about which everyone cares, soil scientists should support and amplify diverse perspectives (Carter et al., 2021). Soil science communications must better represent communities, practitioners, and land users that have historically been left out of these conversations. Critical perspectives have been missing in communication efforts, even though global soil and environmental crises disproportionally impact marginalized and vulnerable communities (Berhe, 2020). Therefore, soil ecologists must both provide consistent messages about soil biodiversity conservation and support diverse voices in framing those messages in ways that resonate with different audiences. Only then, can soil conservation be everyone's issue and not that just of soil scientists.

Further, the pool of communicators who talk and write about soil biodiversity should be expanded. Soil science is one of the least diverse subdisciplines in environmental science when evaluated across several axes of identity including ethnicity, gender, socioeconomic status, and disability, among others (e.g., Carter et al., 2021; Vaughan et al., 2019). Members of marginalized communities have also been overlooked or excluded from science communication and a focus on inclusion and equity in the discipline is needed (Dawson, 2014; Canfield et al., 2020). Individual actions scientists can take to address gaps include acknowledging the exclusion of diverse voices in soil science communication, amplifying the work of diverse scholars and communicators, and learning the local history of the soils about which one communicates. Institutions can contribute to this goal by financially supporting soil science communication efforts and recognizing it as part of evaluation and promotion pathways.

4. Conclusion

Soil ecologists have both a responsibility and opportunity to shape discourse and policy priorities around soil biodiversity conservation. In our review of soil-related editorials, we found that while biodiversity was often mentioned, it was not the most common key message compared to those focused on food and fiber production, climate change, and water resources. We also found that authors framed essays around economic development, scientific and technological uncertainty, and morality and ethics, but opportunities to apply other persuasive strategies still remain. Informed by this review, we provided recommendations for soil ecologists communicating about soil biodiversity including considering the audience and clarifying key messages, drawing from science communication research to select a persuasive frame, and amplifying diverse voices and perspectives with consistent messaging. When soil ecologists apply these recommendations to refine communication strategies within the discipline, non-soil ecologists will become more equipped to communicate about soil biodiversity. Helping the public and non-soil scientists see soil biodiversity conservation as "their" issue will ensure that people want to increase their knowledge and actions around it (Loyau and Schmeller, 2017). We call on soil ecologists to help others speak for soil life.

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CRediT authorship contribution statement

Meena M. Balgopal: Writing – review & editing, Conceptualization. **Bailey M. McClymonds:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Yamina Pressler:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

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.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.pedobi.2024.151003.

Data availability

Data will be made available on request.

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