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Soil health: A common focus for one health and planetary health interventions

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ABSTRACT

Proponents of both the One Health and Planetary Health paradigms have acknowledged that current methods of agricultural food production are driving many environmental changes with negative human health consequences, including climate change, deforestation, and the emergence of zoonotic disease and antimicrobial resistance. Currently, the training of human health, veterinary, and public health professionals typically does not include aspects of soil health. Much of the resultant discussion in One Health and Planetary Health circles regarding interventions to address the health impact of agricultural practices has focused on measures such as advocating for dietary change toward plant based diets and increasing food safety, biosecurity, disease surveillance and antimicrobial stewardship. A greater understanding of soil health and its relationship to agricultural practices could prove foundational to many of the problems that the One Health and Planetary Health perspectives aim to address, including antimicrobial resistance, zoonotic disease emergence, food security, and climate change. A consequent global focus on the health of soils offers a promise of specific opportunities for preventive interventions and a greater convergence between the One Health and Planetary Health approaches.

The One Health and Planetary Health perspectives attempt to bridge fields historically partitioned into distinct intellectual silos. While both approaches stress the importance of agricultural production to human (and animal) health, the training of human health professionals typically does not include aspects of agriculture, while agronomists don't learn about public health. Yet a greater understanding of soil health and its relationship to agricultural practices could prove foundational to many of the problems that One Health and Planetary Health initiatives aim to address, and a global effort to assess and improve the health of soils would support novel preventive interventions in both agriculture and medicine [1].

Soil health may be defined as "the continued capacity of soil to function as a living ecosystem that sustains plants, animals, and humans" [2]. It is reflected in the physical, chemical, and biological state of a soil and thus through communities of soil life supported by soil organic matter. Indeed, soil life and organic matter are foundational for soil health and soil carbon sequestration [3], nutrient cycling that provisions crops with micronutrients and phytochemicals [1], limiting opportunities for pathogens [4], and sustaining yields with lower nitrogen fertilizer and fossil fuel use [5].

The One Health concept grew out of the accelerating pace of emerging zoonotic disease outbreaks, and One Health efforts to combat emerging zoonoses have included heightened biosecurity and surveillance, improved control of livestock diseases, and attempts to limit the spread of antibiotic resistance [6,7]. Yet while recent reviews have noted the relevance of soil microbiomes to the One Health concept [8,9], and a connection between One Health, soil, and the concept of ecosystem services [10] soil health as an area for action is not mentioned in the recent One Health Joint Plan of Action adopted by the quadripartite World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), the World Organization for Animal Health (WOAH), and the United Nations Environmental Program (UNEP) [11]. Nor is soil mentioned in recent publications by the One Health High Level Panel regarding zoonotic disease risks [12].

The Planetary Health concept [13] has been described as broadening the One Health approach to encompass ecosystem and biosphere level effects, and which considers planetary biogeochemical boundaries to ecosystem disturbance brought on by climate change, global biodiversity loss, air pollution, and disruption of carbon and nitrogen cycles. Yet the Planetary Health literature has included little discussion of soil

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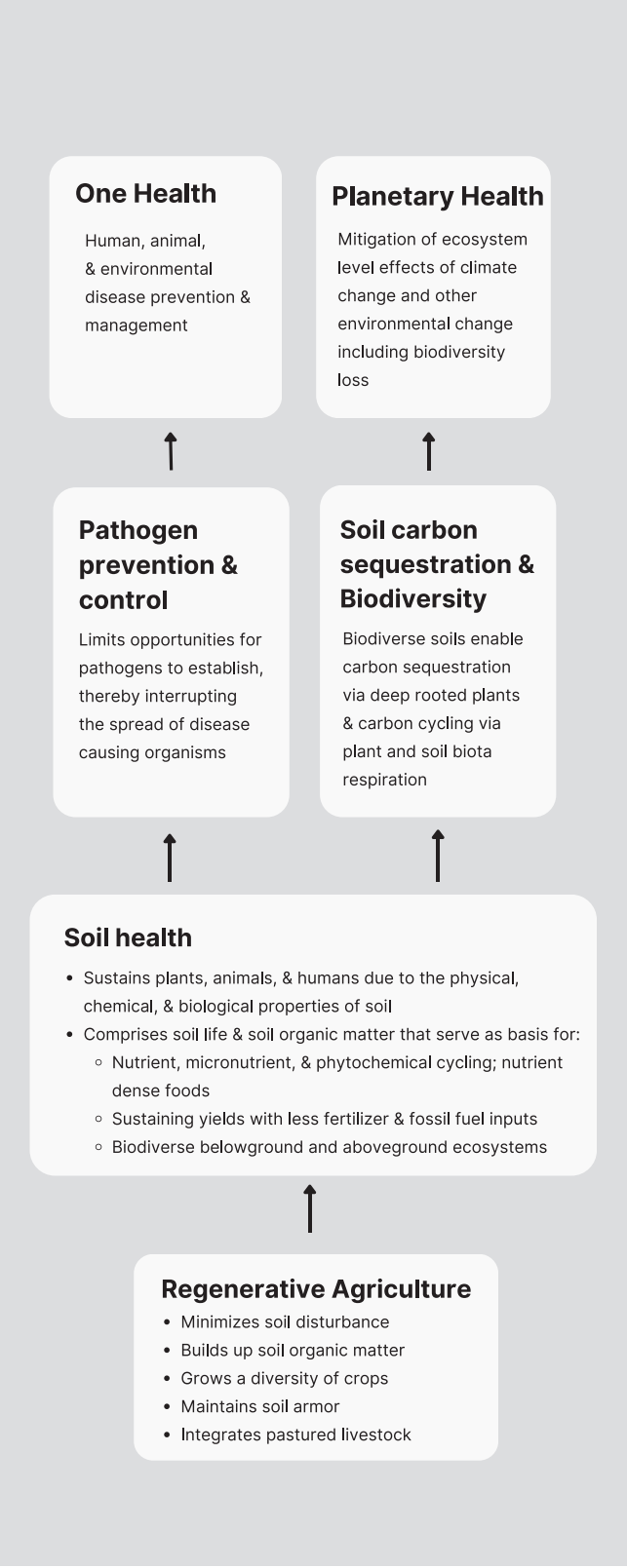

Fig. 1. Flow diagram illustrating how agricultural practices that support soil health provide a common foundation for One Health and Planetary Health. Diverse plantings and integration of livestock drive soil biodiversity and healthy microbiome communities. A focus on rebuilding soil health and biodiversity can therefore help to address a number of "wicked problems" relevant to the priorities of both approaches.

degradation within the planetary boundaries framework [14]. Although some have recognized the connection of soil health to Planetary Health, specific Planetary Health efforts regarding agriculture have focused on antimicrobial resistance [15] and the promotion of plant-based diets to reduce greenhouse gas emissions [16,17], with only passing discussion of the agricultural techniques involved in such change.

Interventions focused on rebuilding soil health could help address a number of challenging problems relevant to the priorities of both One Health and Planetary Health approaches (Fig. 1). By reducing pesticide use and promoting crop diversity, regenerative farming methods can enhance the biodiversity of agricultural fields and soil microbiomes, something essential for global biodiversity conservation given the global acreage that agriculture consumes. Better awareness and management of soil health could help reduce the risk of soil-associated pathogens [18]. The global spread of antimicrobial resistance may be slowed by better management of soil microbiomes, although such efforts must address the underlying complexity of soil biota [15].

Treating healthy soil as fundamental to human health emphasizes the importance of soil biology and microbial ecology to treat soil as a living ecosystem that fosters agricultural productivity. Regenerative methods of agriculture combine minimizing or eliminating mechanical and chemical disturbance of the soil, building up soil organic matter through cover cropping, compost, or manure, and growing a diversity of crops either through companion cropping or diverse crop rotations [5].

Combinations of soil-building practices are central to regenerative agriculture [19]. Shifting to no-till practices minimizes physical disturbance of the soil, and even low-till methods may sustain soil health in settings with high inputs of organic matter (e.g., through additions from compost, manure or cover crops). Minimizing or eliminating the use of chemical fertilizers and pesticides helps to re-establish diverse communities of soil life that can support crop health, and thereby reduce the need for chemical inputs in the first place. Planting cover crops between cash crops so as to always keep a living plant growing in the soil promotes continual production of exudates that support soil life [20]. Diverse crop rotations and cover crop mixes increase the diversity of soil life, resulting in more complex and resilient communities of soil organisms.

Building soil health delivers a range of benefits [5]. Reducing both on-farm fuel usage and synthetic nitrogen fertilizer application, farming methods that rebuild soil organic matter and fertility can help reduce agricultural CO_2 emissions and help maintain crop yields in a post-fossil fuel era [5,21]. Increasing soil organic matter will also contribute to short-term carbon sequestration efforts. Reduced input costs that increase the profitability of farms can contribute to rural livelihoods and promote economic revitalization of rural communities [5,22]. Using less nitrogen fertilizer also reduces on and off-farm pollution. Finally, regenerative practices appear to result in foods with higher levels of certain mineral micronutrients and phytochemicals [1,23].

Regenerative agricultural practices can reduce exposure to human pathogens and antimicrobial resistant bacteria through intensive composting. Well-managed compost systems mitigate the potential for human pathogen transmission from livestock manure [24]. Moreover, living soils are aerobic systems with microbial predators that reduce the survival and transmission potential of dominantly anaerobic human pathogens. Recycling well-composted organic wastes through healthy soils minimizes downstream infection risk to human populations.

Reconsidering environmental and health effects of the human diet through the lens of soil health highlights the fact that the solution is not simply to promote plant-based versus animal-derived diets. The ways that both plants and animals are raised are primary determinants of their environmental and human-health impacts. A plant-based diet grown with farming methods that erode or degrade the soil is not sustainable [25]. Moreover, regeneratively grazed, 100% grass-fed meat and dairy have both a lower environmental footprint and a healthier fat profile than conventionally grain-fed feedlot meat and dairy [1].

Consider too that total ruminant abundance in North America is not

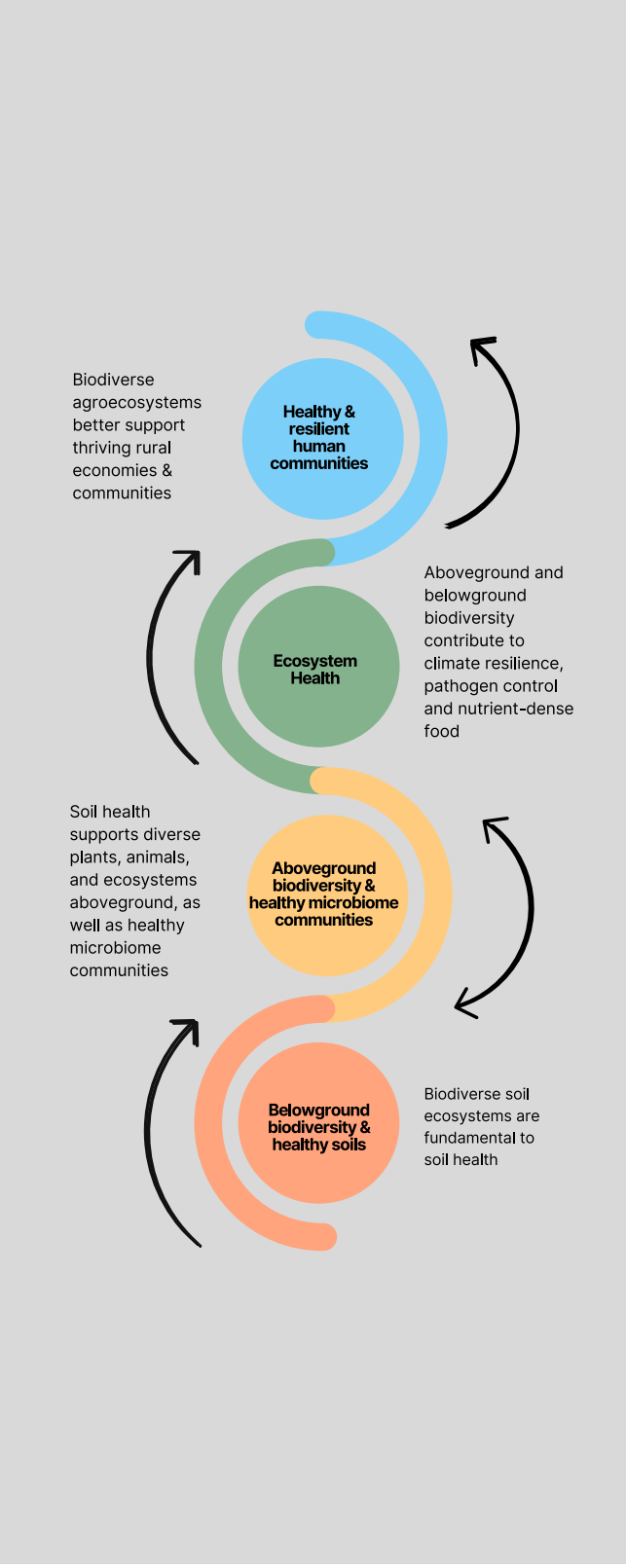

Fig. 2. Biodiverse soil ecosystems, with healthy soils, are fundamental to ecosystem health and human health. Farming practices that foster soil as a living ecosystem support both aboveground and belowground biodiversity, launch an upward cascade of diversity that leads to aboveground biodiversity, and ultimately to healthier and more resilient human communities.

much higher now than in pre-colonial times [25]. Indeed, the key environmental problem with livestock is not that we raise and eat them, but how we raise and feed them. Cattle fed conventionally grown grains in feedlots instead of grazing living plants on regeneratively managed pastures have greater environmental impact and produce less nutritious meat and dairy products [1]. When animals are pastured, manure and microbes get returned to soils where carbon can be sequestered and cycled seasonally. In addition to pastured ranching, integrating livestock with crop production provides additional strategies for recoupling nutrient and carbon cycling, through, for example, controlled rotational grazing and "silvopasture" that integrates grazing animals with trees and forages.

Building healthy soils through the way that food is grown or raised is both scale and diet independent [5]. Large, highly mechanized farms are not inherently bad for the land, and animal husbandry is not synonymous with feedlots. While industrial agriculture practices have often degraded the soil and turned livestock manure into industrial waste rather than using it to build and maintain soil fertility, regenerative practices can be implemented on both small and large farms [5].

Fostering the soil as a living ecosystem launches a cascade of diversity that can ripple upward and downward from the impact of diverse planting and animal exposure on soil microbiomes [26] to aboveground biodiversity and healthier, more diverse human communities (Fig. 2). In soils and people alike, microbial and dietary diversity translate into resilience and disease protection [27]. Building soil organic matter and soil biodiversity is the key to increasing yields with lower fossil fuel and agrochemical use, a combination that enhances farm profitability and rural livelihoods while delivering healthier food to consumers. Farming practices that build healthier soils also support environmental justice in relation to farmers and agricultural workers potentially exposed to lower levels of fewer agrochemicals. And while regenerative agriculture may result in increased labor needs on some farms, these costs can be offset by decreasing agrochemical inputs, a combination that would contribute to supporting robust and thriving rural economies and communities.

Steps that the One Health field could take to incorporate soil health principles include training and education initiatives to improve the agricultural literacy of health professionals. Research initiatives could explore the epidemiological associations between soil characteristics and health outcomes in farms and communities. Intervention studies could similarly assess the impact of changing agricultural practices on specific pathogens such as nematodes [28] as well as short- and long-term health outcomes for animals and humans. Unlike prior technology-driven agricultural revolutions, a soil health revolution driven by principles of ecology and biodiversity would provide a unifying paradigm around which to design interventions in farming practices and technologies that benefit the health of humans, animals, and the environment.

Declaration of competing interest

One of the authors: (DRM) has published books on the topic of soil health.

Data availability

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

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