Nematodes and Soil Health Management

Session: Soil Health

Time: Wednesday December 7th 2:00-2:30 p.m.

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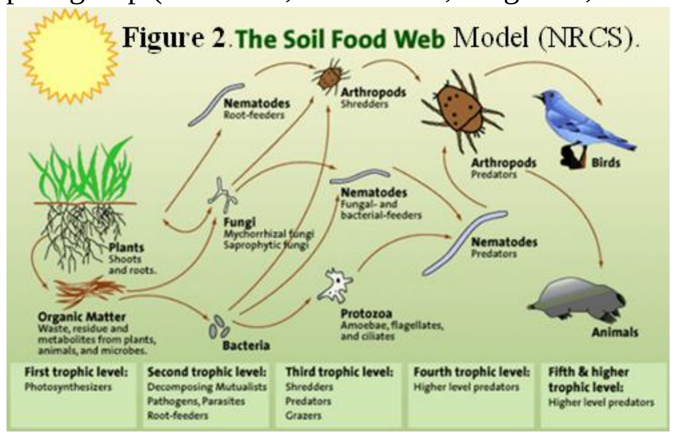
Background: Intensive agricultural practices (APs) have resulted in serious soil health and environmental degradation globally over decades. The agrobiological, economic and environmental benefits of improving soil health are well documented (2-4, 6, 7, 11, 12). As part of reversing and/or preventing soil health degradation, the USDA-Natural Resources Conservation Service (NRCS) has been actively promoting the use of regenerative APs such as diverse cropping systems, conservation tillage and soil amendments, to mention a few. There is considerable basic science and popular literature that links regenerative APs, nematodes and/or soil health, but integrated translation of the science into practical application has multi-layered gaps (6-9, 11, 12). Most of the information exists in disciplinary silos and is highly variable by crop, soil type and location. In order to bridge the gaps, it is necessary to have a **conceptual** understanding of what the **i**) components of soil health and the process-based indicators are and **ii**) role of the soil food web (SFW) in nutrient cycling and soil health and the role of nematodes therein, and **iii**) how changes in nematodes population dynamics in response to AP treatments can be a diagnostic tool for identifying desirable soil health outcomes and a platform for an integrated approach for translating basic science into practical application.

Soil health - "*the capacity of a soil to function*" (1)- has a) biological, b) physiochemical, c) nutritional, d) structural and e) water-holding integrity components that need to be balanced at all times. Soil health and soil quality are considered interchangeable terms (8). All APs alter soil health components directly or indirectly. The NRCS maintains an up-to-date information database on advances in basic and applied aspects of soil health components and has identified six biophysicochemical process-based indicators (Fig. 1A-D). These are organic matter recycling and carbon sequestration, soil structure stability, general microbial activity, carbon food source, bioactive nitrogen, and microbial community diversity (A). Additional information on the components of the physical (B), chemical (C) and biological (D) indicators is also provided. As good and useful as these soil health indicators are, it is difficult to collectively relate them to a specific soil health value that reflects the five components of soil health for a given crop and soil type. Consequently, application of these soil health indicators remains discipline centered. In part, integrated application is limited by variable definitions of what a health soil is.

Figure 1. The six biophysicochemical process-based soil health indicators (A) and the components of B) physical (B), chemical (C) and biological (D) indicators. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=stelprdb1237387.

A healthy soil is one that generates 3 desirable sets of ecosystem services **simultaneously**. These are: **a)** improve soil structure, physicochemistry, nutrient cycling, and water holding capacity, **b)** suppress pests and diseases while increasing beneficial organisms in the same environment, and **c)** improve biological functioning and crop yield. It is critical to understand how the SFW drives the biophysicochemical processes that generate the soil health indicators (Fig. 1) and the role of harmful (herbivore) and beneficial (bacterivore, fungivore, predator and omnivore) nematodes therein. As depicted in the Figure 2 (from NRCS), the SFW has five trophic levels comprising photosynthesizers (Level I), decomposers and parasites (Level II), shredders (Level III), predators (Level IV), and higher-level predators (Level V). Nematodes are central players in Levels II, III and IV (5, 10). **First**, by feeding on or being food for others, nematodes contribute to the nutrient cycling. **Second**, nematodes being the most abundant metazoan found in all terrestrial and aquatic ecosystems makes them an excellent indicator of belowground changes.

Most diagnostic laboratories identify nematodes at the trophic group (herbivore, bacterivore, fungivore, predator and omnivore) level and generate valuable information that parallels Fig 1. However, the best attributes of nematodes as indicators of the biophysicochemical process-based soil health outcomes is yet to be fully realized (9). Nematode trophic groups include those that reproduce like elephants (*few*) and mice (*many*). Based on their reproductive strategy, life history and resistance to disturbance, trophic groups have five colonizer-persister (cp) groups ranging from cp 1 (*fast and resistant*) to cp 5 (*slow and sensitive*) (5). *In order to get a full picture of the role of nematodes in the SFW, nematodes need to be quantified at the trophic and cp group levels*.



There are ecological, biological and biophysicochemical principles driving changes in nematode population dynamics in any given environment where AP treatments are applied. Quantifying changes in nematode population density at the trophic and cp group levels and relating their reproduction and resistance to disturbance functions can be a diagnostic tool for soil health outcomes (Fig. 3). Without going into the mathematical equations, Ferris et al. (5) developed a SFW model that relates changes in nematodes population density as a function of reproduction and food (Enrichment Index, EI) and resistance to disturbance (Structure Index, SI) (Fig. 3). Regressing EI (y-axis) against SI (x-axis), reveals four quadrants: enriched but unstructured (Quadrant A), enriched and structured (Quadrant B), resource-limited and structured (Quadrant C), or resource-depleted with minimal structure (Quadrant D). Enriched means nitrogen (N) is available, limited means N is held in the organisms, and depleted means N is not available. Quadrant B is desirable for agroecosystems where the SFW condition is nutrient enriched and decomposition process is balanced [5].

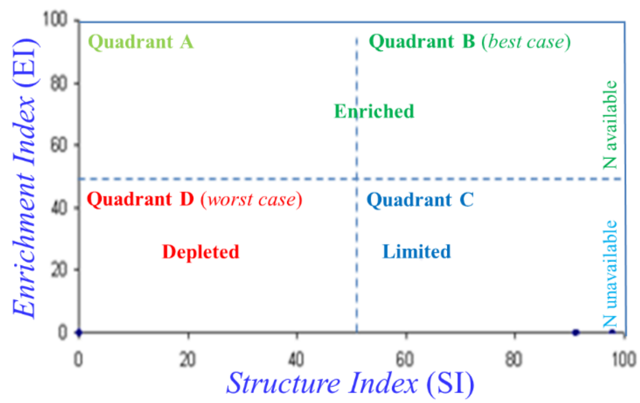


Figure 3. Modified Ferris et al. (5) SFW model.

The Ferris et al SFW model may be expensive, but it is a diagnostic tool that can be **i)** a guide to knowing soil health conditions before AP treatments are applied and the outcomes afterwards and **ii)** an integration platform for the biophysicochemical process-driven soil health indicators described in Fig. 1 are realized. *Without decision-making tools such as the SFW model, we will keep adding to the science and fall short on integrated translation of the science into practical application.*

Selected References: **1.** Anon. (2022). NRCS. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/newsroom/releases/?cid=NRCSEPRD1420430. **2.** Beehler J. et al. (2017). *J. Soil Water Conservation* 72, 272-279. **3.** Bowman, M. & Lynch, L. (2019). *Choices* 34, 1-8. **4.** Brainard**,** D.C. & Noyes, D.C. (2012). *HortScience* 47, 1073-1079. **5.** Ferris, H. et al. (2001). *Applied Soil Ecology* 18, 13-29. **6.** Fine, A.K. et al. (2017). *Soil Scie. Soc. America Journal 81*, 589. **7.** Jian, J. et al. (2020). *Nature & Science Data 7*, 16. **8.** Lehman, R.M. et al. (2015). *Sustainability* 7, 988-1027. **9.** Melakeberhan, H. et al. (2021). *Soil Systems* 5, 32. **10.** Sanchez-Moreno, S. (2018). *Acta Horticulturae* 1196. **11.** van Es, H.M. & Karlen, D.L. (2019). *Soil Scie. Soc. America Journal* 83, 721-732. **12.** Wander, M.M. et al. (2019). *Frontiers of Environmental Science 7*, 1-9.