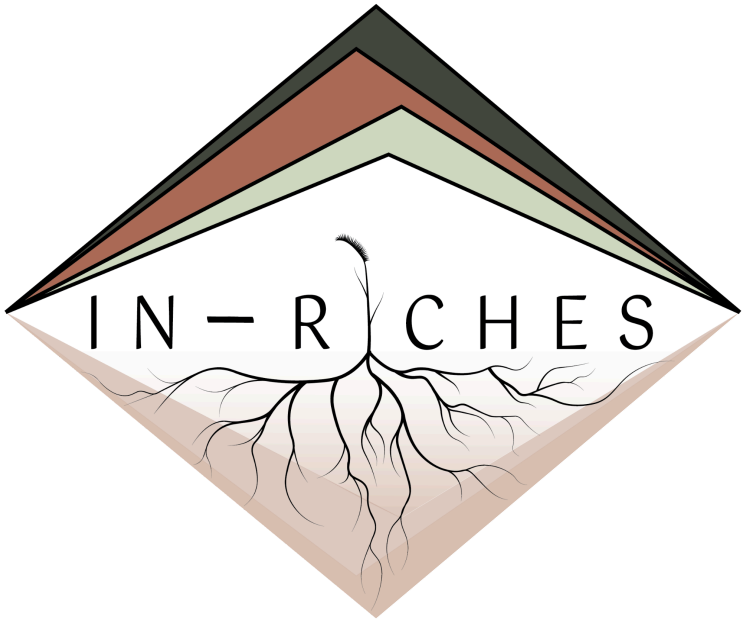
Exploring Soils

Resources to understand the role of soil health in sustainable food systems



Integrated Rocky Mountain-region Innovation Center for Healthy Soils (IN-RICHES)
2024

Special thanks to Emily Holleran, ALM (Adjunct Professor of Sustainability - Harvard Extension School and Arizona State University)

About IN-RICHES

At IN-RICHES, our mission is to create systems level change that scales regenerative soil health systems in the Rocky Mountain region and beyond.

IN-RICHES takes a holistic approach to soil health, integrating cutting-edge science, practical knowledge, policy, and community engagement to make climate-smart decisions.

We collaborate with researchers, land managers, policymakers, and other stakeholders to develop and implement innovative solutions.

We believe that healthy soils are the foundation of a resilient and sustainable food system, a thriving environment, and a prosperous society.

For more information, visit our website at inrichsoil.com.

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Introduction

At IN-RICHES, our mission is to create systems level change that scales regenerative soil health systems in the Rocky Mountain-region and beyond. A critical component of achieving our mission to provide educational resources to audiences outside the agricultural sector. As one stakeholder put it, “If we continue to talk about soil health as an agricultural problem, it will remain an agricultural problem.”

Soils are the foundation of food security, ecosystem health, and economic resilience, and therefore advancing soil health is our collective responsibility. Whether you are farmer, rancher, agricultural professional, or a consumer, everyone has a role to play in advancing soil health.

The purpose of these materials is to provide a starting point from which to think critically and holistically about the soils as the foundation for sustainable and resilient agriculture. While the primary focus of this material is in the context of the United States, you will also find materials that touch on the global context.

These materials are adapted from the “Role of Soil Health in Sustainable Food Systems” offered by Emily Holleran and Helen D. Silver at the Harvard Extension School. The materials below are meant to provide a starting point for the following topics:

1. The basic science of soil health and agricultural management practices;
2. The important role that soils play in our food systems;
3. Political and economic factors that affect agricultural soil health;
4. Resources that provide alternative political and economic pathways that may advance soil health, sustainable and resilient food systems, and robust rural communities.

We can envision several uses of these materials, and we hope you find others. Some include:

- Independent study;
- The basis for book clubs or reading groups; and
- Teaching materials (recommended at a high school level and above)

We have organized these readings into eight main topics, some of which have subtopics. These are:

1. Introduction to Soil Health;
2. Natural Systems, consisting of four subtopics: 1) Soil and Water; 2) Soil Macronutrients, Food Web, and Ecology; 3) On-farm and Genetic Diversity; and 4) Climate;
3. Livestock;

4. Science and Practice, consisting of: 1) Established practices & Economics of Soil Health Practices and 2) Alternative Frameworks and Practices;
5. Economic and Political Factors Affecting Soil Health with Part 1 focusing on the United States and Part 2 focusing on developing countries;
6. Key Responses to Soil Degradation with 2 subtopics: 1) policy changes in industrial agricultural systems and 2) carbon markets and procurement Opportunities;
7. Paths Forward

These materials may be further subdivided into: 1) Recommended Readings; 2) Optional Readings; and 3) Cool Tools.

Finally, this reading list is meant to serve only as a starting point. A plethora of materials exists on each of these topics. For instance, two resources in their entirety serve as excellent resources on the science of soil health and agroecology: 1) Magdoff & Van Es (2021). Building Soils for Better Crops and 2) Gliessman, S. (2015). *Agroecology: The ecology of sustainable food systems* (3d ed.). Boca Raton, FL, US: CRC Press. An excellent source for a history of the US Farm Bill is Imhoff, D. (2019). The Farm Bill: A citizen's guide. Island Press.

We hope these materials inform you and inspire you!

Disclaimer: The purpose of these materials is to spur thought and innovation, therefore the positions of authors and/or organizations included in these materials does not reflect endorsement by either Colorado State University or IN-RICHES.

Topic 1: Introduction to Soil Health

Recommended Readings

Utah Conservation Districts. (2018). The 5 Principles of Soil Health.

Weil, R., & Brady, N. (2017). *The Nature and Properties of Soil*. Pearson Education, Inc. Chapter 1 - pp. 1-32

Montgomery, D. (2017). Growing a Revolution. Introduction, Fertile Ruins, Myths of Modern Agriculture, & The Oldest Problem.

Maharjan, B., Das, S., & Acharya, B. S. (2020). Soil Health Gap: A concept to establish a benchmark for soil health management. *Global Ecology and Conservation*, *23*, e01116. https://doi.org/10.1016/j.gecco.2020.e01116

Optional Readings

United Nations Food and Agriculture Organization. (2018). *The future of food and agriculture: Alternative Pathways to 2050*. (Challenges Ahead for Food and Agriculture, pp. 7-34)

Sustainable Agriculture Research and Education. Soil Health Principles (Ray Archuleta). 2017.

Lehmann, Johannes, Bossio, Deborah A, Kögel-Knabner, Ingrid, & Rillig, Matthias C. (2020). The concept and future prospects of soil health. *Nature Reviews Earth & Environment*, *1*(10), 544-553.

Kiss the Ground. (2020). Kiss the Ground.

Topic 2: Natural Systems
Part 1: Soil and Water

Recommended Readings

Magdoff, Van Es - Building soils for better crops (2021).Chapter 5 (Soil Particles, Water, Air), Chapter 6 (Soil Degradation: Erosion, Compaction, and Contamination)

South Dakota State University Extension. (2014, January 22). Rainfall Simulator - Soil management impacts on water filtration.

University of Iowa Extension Services. (n.d.). Soil health assessment series. (Watch videos 1-5)

IN-RICHES (2023). Rocky Mountain Region In-field Soil Health Assessment Guide.

Optional Readings

Weil, R., & Brady, N. (2017). The Nature and Properties of Soil. Pearson Education, Inc. Chapter 17 pp. 818-877 (Soil erosion and its control)

Kuhn, N. (2014). Soil loss . In G. Churchman, & E. Landa, *The Soil Underfoot: Infinite Possibilities.*

Colorado State University Extension (Master Gardener Program). (2020). Botany. In Garden Notes (pp. 120-160).

New South Wales Government (Industry and Investment) (Australia). (2009). Irrigation salinity - causes and impacts.

UN Food and Agriculture Organization, & International Water Management Institute. (2018). *More people, more food, worse water?*

Cool Tools

USDA Cropscape (Allows for multi-year analysis of land use (e.g., crop type))

USDA Web Soil Survey (Allows for analysis of soils at a given site)

USDA Geospatial Data Gateway (Data downloads available for a variety of soils, climate, and elevation maps)

USDA RUSLE2 (Revised Universal Soil Loss Equation, Version 2) (Allows for the input of tillage information to calculate erosion impacts and Soil Tillage Intensity Rating (STIR)) value

Topic 2: Natural Systems
Part 2: Soil Macronutrients, Food Web, and Ecology

Recommended Readings

Magdoff & Van Es (2021). Building Soils for Better Crops. Chapter 2 (Organic Matter: What It Is and Why It's So Important); Chapter 3 (Amount of Organic Matter in Soils); Chapter 4 (The Living Soil).

University of Iowa Extension Services. (n.d.). Soil health assessment series. (Watch videos 6-9)

Optional Readings

FAO. (2020). *State of knowledge of soil biodiversity—Status, challenges and potentialities.*

Mighty Microbes YouTube Channel

Lori, M., Symnaczik, S., Mäder, P., De Deyn, G., & Gattinger, A. (2017). Organic farming enhances soil microbial abundance and activity-A meta-analysis and meta-regression. *PloS One*, *12*(7), e0180442.

Fierer, Noah, Wood, Stephen A, & Bueno de Mesquita, Clifton P. (2021). How microbes can, and cannot, be used to assess soil health. *Soil Biology & Biochemistry*, *153*, Soil biology & biochemistry, 2021-02, Vol.153.

Cobb, A. (2022). Allies in the Soil: Mycorrhizal FungiAllies in the Soil: Mycorrhizal Fungi

Cool Tools

USDA NTT (Nutrient Tracking Tool)

NTT Instructional Video

Topic 2: Natural Systems
Part 3: On-Farm and Genetic Diversity

Recommended Readings

Gliessman, S. (2015). *Agroecology: The ecology of sustainable food systems* (3d ed.). Boca Raton, FL, US: CRC Press. Chapters 14-16

- Gliessman Chapter 14 Population Ecology of Agroecosystems.pdf
- Gliessman Chapter 15 Genetic Resources in Agroecoysystems.pdf
- Gliessman Chapter 16 Species interactions .pdf

National Academies of Sciences and Engineering (Committee on Genetically Engineered Crops: Past Experience and Future Prospects). (2016). *Genetically Engineered Crops: Experiences and Prospects*. National Academies Press. https://doi.org/10.17226/23395 (Read Report Brief; full report also available)

Wise, T.A. (2019). *Eating Tomorrow: Agribusiness, Family Farmers, and the Battle for the Future of Food*. New York, NY: The New Press. Monsanto Invades Corn's Garden of Eden in Mexico

Optional Readings

Davis, D. R. (2009). Declining Fruit and Vegetable Nutrient Composition: What Is the Evidence? HortScience, 44(1), 15–19.https://doi.org/10.21273/HORTSCI.44.1.15

Montgomery, D. & Bikle, A (2022), What your food ate. pp. 87-104 & 147-164 (References for What your food ate are here)

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (2016). *The assessment report on pollinators, pollination and food production (Summary for policymakers).*

Chester, J. The Biggest Little Farm. 2019. Available on a variety of streaming sites (You Tube, Amazon Prime, Google Play)

Kempf, J. (2020, June 16). Regenerative Agriculture Podcast: Embracing the connection between agriculture and health with Zach Bush.

Geiger, F., Bengtsson, J., Berendse, F., Weisser, W., Emmerson, M., Morales, M., . . . Tscharntke, T. (2010, March). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic and Applied Ecology, 11*(2), 97-105.

Cameron, S. A., Lozier, J. D., Strange, J. P., Koch, J. B., Cordes, N., Solter, L. F., & Griswold, T. L. (2011). Patterns of widespread decline in North American bumble bees. *Proceedings of the National Academy of Sciences, 108*(2), 662–667.

Topic 2: Natural Systems
Part 4: Climate

Recommended Readings

US Global Change Research Program. (2023). Fifth National Climate Assessment - Chapter Eleven - Agriculture, Food Systems, and Rural Communities.

UN Food and Agriculture Organization. *Climate change and food security: risks and responses*. (2015).

Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for Sustainable Development, 35*(3), 869–890.

Optional Readings

US Department of Agriculture; University Corporation for Atmospheric Research; National Center for Atmospheric Research. (2015). *Climate change, global food security, and the US food system.*

Diffenbaugh, N. S., Davenport, F. V., & Burke, M. (2021). Historical warming has increased U.S. crop insurance losses. *Environmental Research Letters, 16*(8), 084025. https://doi.org/10.1088/1748-9326/ac1223 and sources cited therein

Topic 3: Livestock

Recommended Readings

Food Climate Research Network. (2017). *Grazed and confused?*

United States Geological Survey, USDA ARS, USDA NRCS, & US DOI BLM. (n.d.). *An Overview of Interpreting Indicators for Rangeland Health.*

USDA Sustainable Agriculture and Research Education Program. (2014, March 28). *Grazing cover crops and benefits for livestock operations - Gabe Brown.*

Optional Readings

Sanderson, J. S., et al. (2020). Cattle, conservation, and carbon in the western Great Plains. *Journal of Soil and Water Conservation*, *75*(1), 5A-12A.

USGS, USDA ARS, USDA NRCS, & US DOI BLM. (2005). Interpreting indicators of rangeland health: Technical reference 1734-6.

Hayek, M. N., & Garrett, R. D. (2018). Nationwide shift to grass-fed beef requires larger cattle population. *Environmental Research Letters*, *13*(8), 084005.

Rutherford. (2018, May 31). *Sheep & cattle? The combination really works*. Beef Magazine.

Cool Tools

USDA and BLM Rangeland Analysis Platform

Grassland Productivity Forecast (Western United States)

Topic 4: Science and Practice 1
Established practices & Economics of Soil Health Practices

Recommended Readings

Magdoff, F., & Van Es, H. (2021). Building soils for better crops (3d ed.). Brentwood , MD: SARE Outreach Publications. (Chapters 8-16)

Derpsch, R., Franzluebbers, A. J., Duiker, S. W., Reicosky, D. C., Koeller, K., Friedrich, T., Sturny, W. G., Sá, J. C. M., & Weiss, K. (2014). Why do we need to standardize no-tillage research? Soil and Tillage Research, 137, 16–22.

TEDx Talks (Grand Forks). (2016, March 29). Regeneration of our lands: A producer's perspective - Gabe Brown.

European Commission. Agriculture and Rural Development. 2023. Using less chemical pesticides: European Commission publishes toolbox of good practices.

European Commission. Integrated Pest Management (IPM). n.d.

Soil Health Institute. (2024). Economics of Soil Health Systems on 30 U.S. Farms. (See in particular, videos, fact sheets, and report "Economics of Soil Health Systems on 100 Farms")

American Farmland Trust & USDA NRCS (2019). Quantifying Economic and Environmental Benefits of Soil Health.

PennState Extension. (2024). *Home Composting: A Guide for Home Gardeners.*

University of Minnesota Extension. (2024). *Composting in home gardens.*

US Composting Council. (2024). *Home Page.* (Lots of good resources)

Optional Readings

Davis, A. S., Hill, J. D., Chase, C. A., Johanns, A. M., & Liebman, M. (2012). Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. *PLoS ONE*, *7*(10), e47149.

Bedoussac, L., Journet, E.-P., Hauggaard-Nielsen, H., Naudin, C., Corre-Hellou, G., Jensen, E. S., Prieur, L., & Justes, E. (2015). Ecological principles underlying the increase of productivity achieved by cereal-grain legume intercrops in organic farming. A review. *Agronomy for Sustainable Development*, *35*(3), 911–935.

Kim, N., Zabaloy, M. C., Guan, K., & Villamil, M. B. (2020). Do cover crops benefit soil microbiome? A meta-analysis of current research. Soil Biology and Biochemistry, 142, 107701.

Bowles et al. (2020). Long-Term Evidence Shows that Crop-Rotation Diversification Increases Agricultural Resilience to Adverse Growing Conditions in North America. One Earth, 2(3), 284–293.

Topic 4: Science & Practice
Alternative Frameworks and Practices

Recommended Readings

USDA. (2023). National Organics Program.

Western Sustainable Agriculture Research and Education. (2017). *Organic Production*. SARE.

Lawton, G. (n.d.). *Permaculture: A Designers' Manual*. GeoffLawton Online.

Optional Readings

Regenerative Organic Alliance. (2024). About.

Regenerative Organic Alliance. (2024). Framework for Regenerative Organic Certified.

Cooper et al. (2016). Shallow non-inversion tillage in organic farming maintains crop yields and increases soil C stocks: A meta-analysis. *Agronomy for Sustainable Development*, *36*(1), 22.

Ferguson, R. S., & Lovell, S. T. (2014). Permaculture for agroecology: Design, movement, practice, and worldview. A review. *Agronomy for Sustainable Development*, *34*(2), 251–274.

Topic 5: Economic and Political Factors Affecting Soil Health Part 1: United States

Recommended Readings

Imhoff, D. (2019). The Farm Bill: A citizen's guide. Island Press. Select portions. pp. 26-33; 49-103.

National Sustainable Agriculture Coalition & Soil Health Institute. (n.d.) Impact of the 2018 Farm Bill Provisions on Soil Health.

Paarlberg, R. (2021). *Resetting the Table*. Alfred A. Knopf. Testing the case against industrial farming (pp. 17-43).

Philpott, T. (2020). *Perilous Bounty*. New York: Bloomsbury Publishing. (Chapter 4 - Empire of Dirt)

Wang et al. (2021). Warming temperatures, yield risk and crop insurance participation. *European Review of Agricultural Economics*, 48(5), 1109-1131.

Optional Readings

Rockefeller Foundation (2022). The True Cost of Food: Measuring What Matters to Transform the US Food System

Philpott, T. (2020). *Perilous Bounty*. New York: Bloomsbury Publishing. (Chapter 8 - The Future of the Farm)

Paarlberg, R. (2013). *Food Politics: What everyone needs to know* (2nd ed.). New York, New York: Oxford University Press. Chapter 8 (The Politics of Farm Subsidies and Trade); Chapter 3 (The Politics of High Food Prices)

Graddy-Lovelace, G., & Diamond, A. (2017). From supply management to agricultural subsidies - and back again? The U.S. Farm Bill & agrarian (in)viability. Journal of Rural Studies, 50, 70-83. doi.org/10.1016/j.jrurstud.2016.12.007

Kirschenmann, F., Stevenson, S., Buttel, F., Lyson, T., & Duffy, M. (n.d.). *Why worry about agriculture in the middle?*

Newman, C. (2020, July 9). Small Family Farms Aren't the Answer. Medium.

McFadden et al. (2017). *The economics of local food systems: A toolkit to guide community discussions, assessments and choices.*

Topic 5: Economic and Political Factors Affecting Soil Health Part 2: Developing Countries

Recommended Readings

Chhetri, N., Chaudhary, P., (2011). Green Revolution: Pathways to Food Security in an Era of Climate Variability and Change? *Journal of Disaster Research*, 6(5), 486–497.

Conway, G. Can Sustainable Intensification Feed the World? *Center on Food Security and the Environment.* (2015)

The Alliance for a Green Revolution in Africa. (2024). *Home page.*

The Alliance for a Green Revolution in Africa. (2024). *Annual Reports.*

Hime, B. (Ed.). (2020). *False promises: The alliance for a green revolution in Africa (AGRA).*

AGRA's response to *False promises*

Wise, T.A. (2019). *Eating Tomorrow: Agribusiness, Family Farmers, and the Battle for the Future of Food.* New York, NY: The New Press. (Chapter 2, The Malawi Miracle and the limits of Africa's Green Revolution)

Wise, T.A. (2019). *Eating Tomorrow: Agribusiness, Family Farmers, and the Battle for the Future of Food.* New York, NY: The New Press. Chapter 9, Trading in Hypocrisy: India vs. World Trade Organization

Norton, R. D. (2004). Agricultural development policy (available for purchase)

United Nations Food and Agriculture Organization. (2018). *The future of food and agriculture: Alternative Pathways to 2050.*

Topic 6: Key Responses

Part 1: Policy changes in Industrial Agricultural Systems (e.g., New Zealand, EU, and US)

Recommended Readings

Imhoff, D. (2019). The Farm Bill: A citizen's guide. Island Press. pp. 185-206.

EU Commission (2023). Future of the common agricultural policy.

European Commission. (2023, December 20). *Soil Health.*

Warren, T. (2020, February 25). *A New Farm Economy*. Medium.

Alliance for Food Sovereignty in Africa; Tanzania Organic Agriculture Movement. (2016). *Agroecology: The bold future of farming in Africa.*

Optional readings

Watnick, D. & Warner, A. (2021). Soil Health Policy: Developing Community-Driven State Soil Health Policies and Programs (Yale Center for Business and the Environment)

Paarlberg, R. (2021). *Resetting the Table*. Alfred A. Knopf. The Limits of Local. pp. 77-111.

Harvard Law School Food Law and Policy Clinic; Center for EcoTechnology. (2019). Bans and Beyond: Designing and Implementing Organic Waste Bans and Mandatory Organics Recycling Laws.

Topic 6: Key Responses

Part 2: Carbon Markets and Procurement

Recommended Readings

World Resources Institute. (2020, August 24). Further Explanation on the Potential Contribution of Soil Carbon Sequestration on Working Agricultural Lands to Climate Change Mitigation.

Schlesinger, W. H. (2022). Biogeochemical constraints on climate change mitigation through regenerative farming. Biogeochemistry. https://doi.org/10.1007/s10533-022-00942-8

Davidson, E. A. (2022). Is the transactional carbon credit tail wagging the virtuous soil organic matter dog? Biogeochemistry, 161(1), 1–8. https://doi.org/10.1007/s10533-022-00969-x

Paarlberg, R. (2021). *Resetting the Table*. Alfred A. Knopf. The Panic for Organic (pp. 112-128)

Center for Good Food Purchasing Program. (2023). Good food purchasing program: Purchasing standards of food service institutions. (Email info@goodfoodpurchasing.org to get a copy of the standards)

De Schutter, O. (2014). The power of procurement: Public purchasing in the service of realizing the right to food. Retrieved from http://www.srfood.org/images/stories/pdf/otherdocuments/20140514_procurement_en.pdf

Cool Tools

USDA and Colorado State University - COMET Planner (Allows for estimates of greenhouse gas impacts estimates from a variety of management changes based on county)

American Farmland Trust - CaRPE Tool (Assists in estimating carbon reduction from implemented soil health practices)

USDA and Colorado State University - COMET Farm (More detailed analysis of greenhouse gas impacts - see website for publicly available trainings)

Topic 7: Paths Forward

Searchinger, T., Waite, R., Hanson, J., Dumas, P., & Matthews, E. (2018). Creating a sustainable food future. pp.55-77

United Nations Food and Agriculture Organization. (2018). The future of food and agriculture: Alternative Pathways to 2050.

Holt-Giménez, E., & Altieri, M. A. (2013). Agroecology, Food Sovereignty, and the New Green Revolution. *Agroecology and Sustainable Food Systems*, *37*(1), 90–102. https://doi.org/10.1080/10440046.2012.716388

Phiri, P. (2014). Community development in Zimbabwe via ecosystem restoration. *Restoring Ecosystems to Reverse Global Warming.*