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An Economic Perspective on Soil Health

by Maria Bowman, Steven Wallander, and Lori Lynch



USDA has championed soil conservation, a suite of efforts to mitigate soil loss due to erosion, since 1935. In that year, Congress created the Soil Conservation Service, predecessor to today's Natural Resources Conservation Service (NRCS). Given this long

Highlights:

- Soil health builds upon soil conservation by

history, a large literature base exists on the costs and benefits of soil conservation and incentives for farmers to adopt soil conservation practices.

Today, NRCS and a multitude of partners are encouraging farmers to think more broadly about “soil health”—a concept that soil scientists have refined over the past two decades. This article discusses some of the economic issues associated with managing for soil health.

Economics of Soil Health: The Basics

NRCS defines soil health as “the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.” Healthy soils have high levels of microbial activity, higher levels of organic matter, and good soil structure. Because soil properties differ according to climate, geology, topography, and land use and management history on a field or farm, “healthy soil” can look very different in different places.

To sustain and improve the health of their soil and reduce erosion, farmers can implement various management practices that have both costs and benefits to the farmer. When farmers make decisions about soil health practices, they are often concerned with whether a practice will improve crop yields and/or reduce agricultural input costs. Other private benefits that might be relevant to the farmer include greater resilience of crops to extreme weather (droughts and floods) and an opportunity to engage in environmental stewardship. Soil health practices can also have benefits for society, including reduced greenhouse gas emissions from agriculture, increased carbon storage, and improved water quality through reduced nutrient and sediment pollution. These public benefits have the potential to affect present and future generations, but farmers may not be considering them when they make decisions about adopting soil health practices.

Another factor that may influence a farmer’s decision to implement soil health practices is the time lag required to achieve improvements in soil health. Often, the costs of adopting a practice happen in early years (for example, buying cover crop seed), whereas improvements in soil health build slowly over time. Even if the benefits to farmers may outweigh the costs over time, financial constraints or uncertainty about the long-term benefits can affect their decisions. A variety of purchased inputs, such as

encouraging farmers to manage soil as a living ecosystem, in addition to reducing soil erosion.

- Healthy soils can have benefits to society (public benefits) and to farmers (private benefits)—but the private benefits may not always be large enough to incentivize farmers to use practices that improve or sustain soil health.
- USDA incentivizes farmers to adopt soil health practices through programs such as the Environmental Quality Incentives Program and the Conservation Stewardship Program.

fertilizer, irrigation water, and pesticides, are substitutes for soil health, and some farmers may decide that increased use of these inputs is a better option than making a long-term investment in soil health.

USDA conservation programs are designed to help overcome situations in which only a small portion of farmers might be willing to adopt conservation practices on their own. Through a number of conservation programs, the U.S. Government provides financial incentives to farmers to adopt soil-health-related practices. As conservation policies and programs evolve, economists are actively researching the costs and benefits of soil health practices, which can provide an economic rationale for paying farmers to adopt soil health practices.

Practices Farmers and Ranchers Can Use To Build Soil Health

Farmers and ranchers use a number of practices and combinations of practices to build or restore soil health. On cropland, these include no-till or reduced tillage, cover cropping, mulching, and nutrient management. For pasture and rangelands, farmers and ranchers seek to balance animal health and weight gain while sustaining forage regrowth and diversity. This usually involves some form of prescribed or rotational grazing (see box “Key Soil Health Practices ”).

For both cropland and pasture/rangeland, NRCS has developed four key principles that farmers, ranchers, and land managers can use to build soil health: keep the soil covered as much as possible, disturb the soil as little as possible, keep plants growing throughout the year to feed the soil, and diversify as much as possible using crop rotation and cover crops. Among the many conservation practices related to soil health, some practices reflect more than one of these principles. For example, cover crops address all four concerns if, after the crops have grown, they are killed in a way that minimizes soil disturbance.

How many farmers already use practices that promote soil health? According to data from the most recent Census of Agriculture, conducted in 2012, the share of farms engaged in some soil health practices and the share of total acres used varies by practice:

No-till: 34.6 percent of acres for which tillage practices are reported.

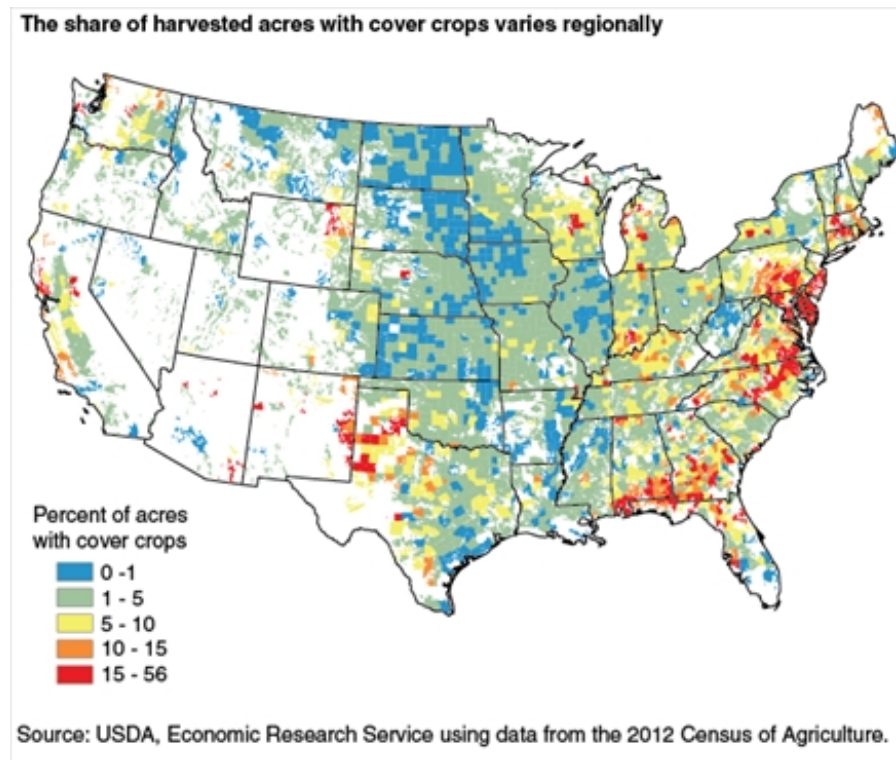
Cover crops: 8.6 percent of farms with cropland and 2.9 percent of cropland acres, excluding idled (e.g., Conservation Reserve Program) acres.

Other types of conservation tillage (such as mulch or ridge till): 27.5 percent of acres for which tillage practices are reported.

These national adoption rates highlight averages but obscure differences in regional, local, or farm-level adoption of soil health practices or variations by sector/crop. For example, a 2015 study by ERS using data from USDA’s Agricultural Resource and

Management Survey (ARMS) found that no-till/strip-till and cover cropping are used more frequently in the southern and eastern regions of the United States, and that no-till/strip-till use is highest on soybean acres (between 40 and 45 percent of soybean acres used no-till in the 2006 and 2012 versions of the survey) when compared to corn, wheat, and cotton acreage.

A number of factors may drive these geographic differences in adoption rates. These include climatic factors; demographic and social factors; differences in State-level policies or regulations; differences in funding for farmer outreach, extension, or conservation payments; and differences in regional agricultural markets. For example, no-till can make soils slower to warm up in the spring, which can make farmers in cooler climates less willing to adopt no-till. In contrast, farmers with steep or exposed land that is more vulnerable to water and wind erosion may use no-till or reduced-till as part of “conservation compliance,” which requires farmers to implement soil conservation plans. Some regions have high rates of cover crop adoption because they pay farmers to grow cover crops (see box “State Programs for Soil Health: Maryland’s Agricultural Water Quality Cost-Share Program”).



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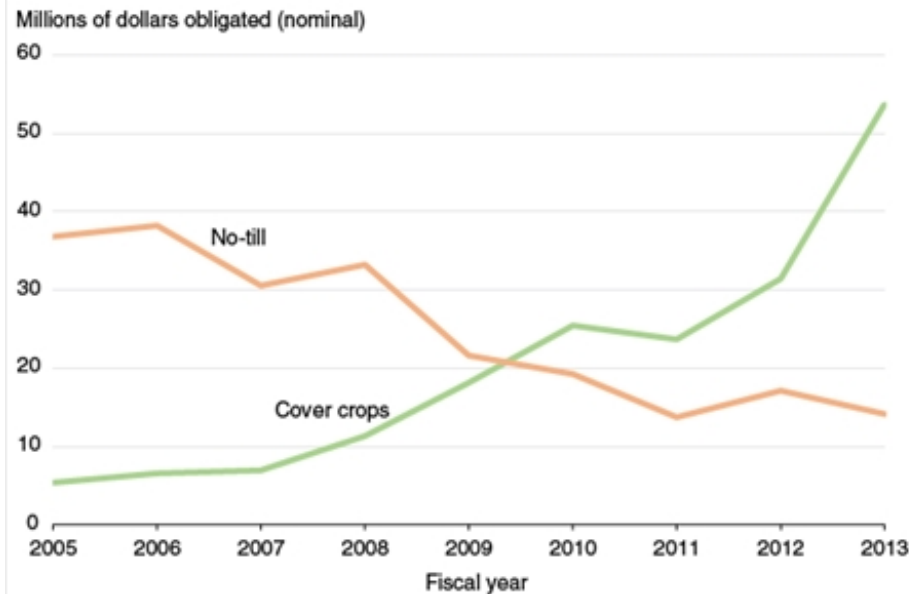
Federal and State Incentives for Soil Health Practices

Soil health is the focus of NRCS's Unlock the Secrets in the Soil program. As part of this campaign, NRCS is educating farmers and others about the science of soil health. Increasingly, this effort is a complement to the suite of USDA working lands programs, which provide technical and financial assistance that encourages farmers to adopt conservation practices. Many of these practices have important soil health benefits.

Two of the main programs from which eligible farmers and ranchers can receive Federal financial assistance for implementing soil health practices on working lands are the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP). In EQIP, farmers receive financial assistance for applying approved practices that address specific resource concerns. In CSP, farmers receive financial assistance for applying conservation enhancements that build on and leverage the performance of existing NRCS-approved conservation practices.

Under EQIP, the most popular soil-health-related practices for which farmers are receiving payments are nutrient management, cover cropping, no-till, reduced tillage, conservation crop rotations, mulching, and seasonal residue management. Between 2005 and 2013, NRCS dramatically increased annual spending on cover crops through EQIP from just over \$5 million to more than \$50 million, and between 2009 and 2014, the number of acres receiving EQIP payments for cover cropping more than doubled (from 312,552 to 825,808). Over the same period, the number of acres receiving payments for no-till declined, as did the total value of no-till payments. One plausible explanation for this trend is that farmers who have used conservation tillage are aware of the private benefits and become more likely to adopt no-till, even without a payment. No-till has also become more feasible as advances in seed technology have made chemical weed control a substitute for tillage. This presents opportunities for the programs to focus on other practices that promote soil health but may have a higher cost to the farmer, such as cover crops.

From 2005 to 2013, an increasing focus on the cover crop practice in USDA's Environmental Quality Incentives Program has mirrored a declining focus on the no-till practice

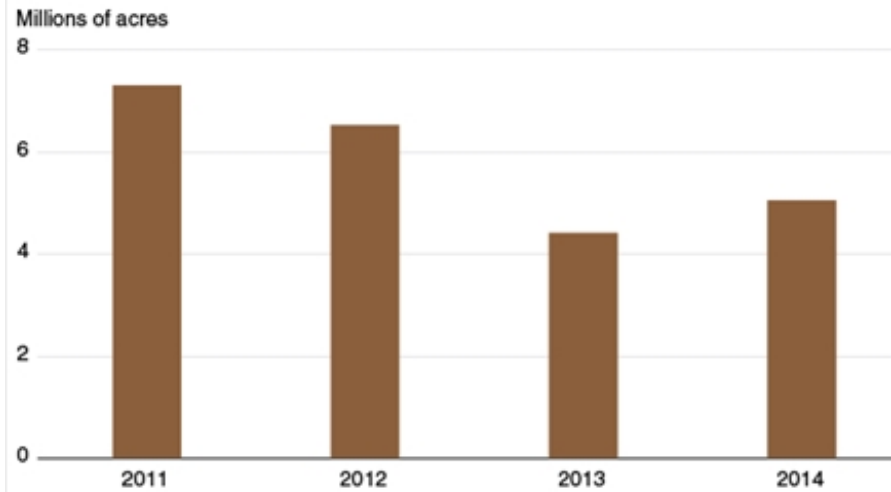


Source: USDA, Economic Research Service calculations using USDA, National Resources Conservation Service, ProTracts database.

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The CSP was established under the 2008 Farm Act. Farmers who have a CSP contract on their farm often implement several environmental practices or “enhancements.” Many CSP practices and enhancements are directly or indirectly related to improving soil health, and some of the most popular practices relate to cover cropping, pasture and rangeland management or restoration, and no-till or reduced tillage. Between 2010 and 2014, the number of acres receiving CSP payments for at least one soil health practice or enhancement grew from just under 7 million to more than 30 million. This amounts to more than 3 percent of total acreage in U.S. farms.

Millions of new acres with at least one CSP soil health practice or enhancement were enrolled in CSP each year (2011-2014)



Note: These data include only active and completed contracts. For contracts that included more than one land unit and/or more than one soil health practice or enhancement, we used the maximum value of the planned acres for each land unit that had at least one soil health practice/enhancement applied (to avoid double counting). CSP = Conservation Stewardship Program. Source: USDA, Economic Research Service calculations using USDA, National Resources Conservation Service, ProTracts database.

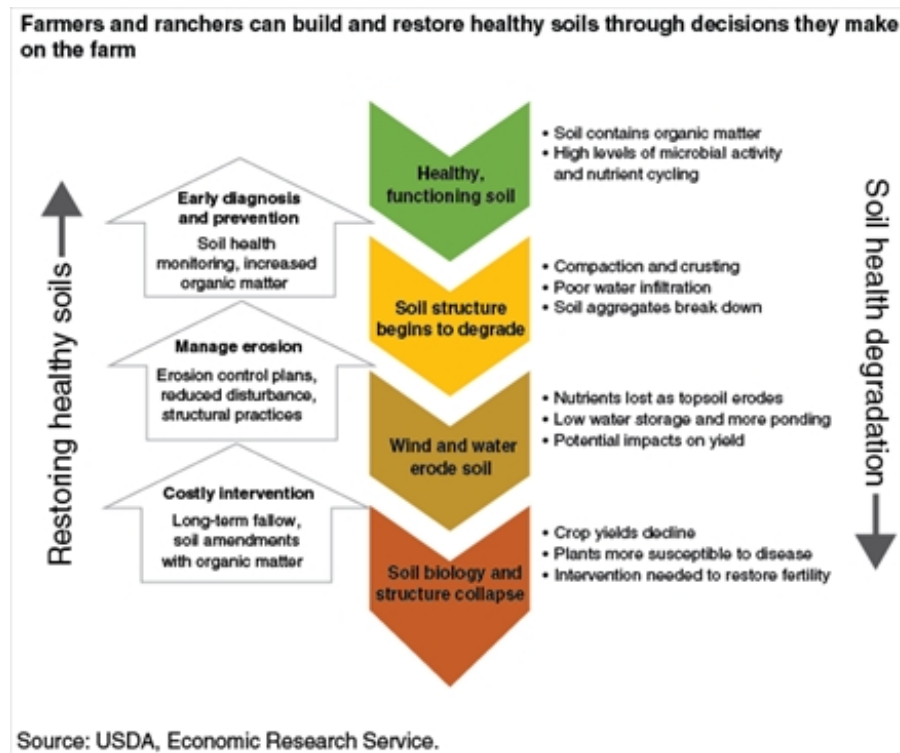
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Several States also have programs in place to motivate farmers to use practices that promote soil health. For example, the State of Maryland pays farmers to plant cover crops to reduce nutrient pollution to the Chesapeake Bay (see box “State Programs for Soil Health: Maryland’s Agricultural Water Quality Cost-Share Program”), and the State of Delaware offers financial assistance for cover crops, grassed waterways, and other practices through its Watershed Restoration and Protection Strategy program.

Managing for More Than Erosion

Historically, most USDA policies have focused on reducing the impacts of soil erosion, which is an intermediate step in the process of soil degradation. Though the rate of soil erosion is influenced by a variety of factors the farmer cannot change, such as the type of soil and the slope of the land, soil erosion can also be a symptom of degraded—or unhealthy—soil. Much in the same way that a healthy diet, an active lifestyle, and stress management are considered important tools for preventing hypertension, diabetes, and heart disease, management practices to build healthy soil are now recognized as important tools to maintain soil structure, biologic

activity, and other properties. These, in turn, can prevent soil erosion and other symptoms.



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Farmers can observe soil erosion. But how do they know if they have healthy soil? Soil scientists have developed an array of indicators that capture the physical, chemical, and biological aspects of soil health. They have also developed tests to provide information to farmers on each of these dimensions. These include in-field testing or scoring systems that a farmer can use without sending soil to a lab, as well as more complex systems that involve lab testing, such as the Cornell Soil Health Assessment. The use of these types of data may indicate that farmers are measuring the health of their soil.

Farmers and scientists can assess soil health in the field and in the laboratory using a variety of indicators

In-field soil health indicators	Indicators of soil health from lab tests
<ul style="list-style-type: none"> ■ Earthworms ■ Organic matter color, roots, and residue ■ Crop condition ■ Subsurface compaction ■ Soil structure ■ Erosion ■ Water-holding capacity ■ Drainage infiltration ■ pH ■ Nutrient-holding capacity 	<ul style="list-style-type: none"> ■ Soil organic matter ■ Soil protein ■ Soil respiration ■ Soil active carbon ■ Available water capacity ■ Surface hardness ■ Aggregate stability ■ Soil chemical composition (pH and plant nutrients)
<ul style="list-style-type: none"> ■ Biological indicators ■ Chemical indicators ■ Physical indicators 	

Note: Some of the in-field indicators in the left column are visual or can be evaluated by digging a small hole or feeling the soil. These include, for example: erosion, drainage infiltration, soil structure, organic matter, earthworms, and crop condition. For the specific indicators in the right column, farmers typically send their soil to a lab to be tested using more involved methods or equipment. Some indicators, such as pH, can be tested or evaluated in the field or in the lab, though lab testing may be more accurate.
 Source: USDA, Economic Research Service using Comprehensive Assessment of Soil Health—The Cornell Framework Manual, 3rd edition, 2016

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Soil scientists now agree that healthy soils have high levels of microbial activity, contain organic matter, and have good soil structure. Possibly the most valuable indicator of soil health is soil organic matter (SOM). SOM has several important benefits, such as improved water-holding capacity and nutrient cycling, and is a good indicator of soil structure and function (including biological functioning). It is also easy to measure—farmers can see their SOM change over time or ask for an inexpensive test in a soils lab (see box “Farmers With Oat and Cotton Fields Measure the Health of Their Soil”).

Economic Issues Associated With Managing for Soil Health

As discussed earlier, a farmer may only manage for soil health if there is a private benefit to the farmer that is greater than the cost of the practices. A variety of conservation programs help encourage adoption of these practices through the provision of technical and financial assistance. To help ensure cost-effective use of program resources for soil health practices, more information is needed on how much farmers benefit from soil health, how shifting the emphasis from soil conservation to soil health influences

farmer motivation to adopt soil health practices, how much it costs farmers to implement soil health practices, and how large the public benefits are from changes in soil health as a result of these practices.

It is also important to understand how farmers and land managers make decisions about when to diagnose and treat soil health concerns. Soil health monitoring and testing for soil organic matter may help farmers identify and address soil degradation sooner than monitoring for soil erosion. Thus, under a soil health perspective, farmers may take actions to improve their soil earlier or engage in a broader range of activities, such as engaging in formal or informal monitoring or testing of soil health properties or planting a cover crop, even if their soil is not severely degraded.

The costs and benefits of early intervention likely differ from the costs and benefits of adopting practices associated with addressing significant erosion concerns. For example, structural erosion control practices are only implemented when erosion control is critical, which means that—from an economics perspective—the benefit of implementing a structural practice might be large because erosion is more severe. However, using a cover crop may be less costly than implementing a structural practice, even if done every year.

Federal and State programs incentivize soil health practices, which contribute to public and private benefits. A better understanding of these benefits relative to the costs of practice implementation, among other research questions, could improve the efficiency of the programs and help inform future soil health research. As we expand our understanding of soil health, conservation policies may also need to consider what motivates farmers to consider soil health, to engage in testing and monitoring of soil health, and to adopt a wide variety of practices that can maintain and restore healthy, functioning soil ecosystems.

Key Soil Health Practices

No-till: Growing crops without tilling (e.g., plowing) the soil.

Reduced-till/mulch-till: Tilling the soil in ways that minimize disturbance to the soil or maintain more residue cover than conventional tillage.

Mulching: Adding plant residue (or other materials) to the surface of the soil.

Cover cropping: Growing a crop, often over the winter, that will be left in place as residue or incorporated into the soil to increase organic matter.

Conservation crop rotation: Choosing crop rotations to maximize crop diversity, build organic matter, and improve soil biodiversity.

Nutrient management: Adjusting the type, location, rate, and timing of fertilizer or other nutrients to meet plant needs and minimize environmental impacts.

Prescribed/rotational grazing: Managing where and when livestock graze in order to prevent overgrazing and to optimize pasture growth.

State Programs for Soil Health: Maryland’s Agricultural Water Quality Cost-Share Program

In 2004, Maryland set a goal to plant 600,000 acres of cover crops each year to meet a Federal “pollution diet” of nutrients and sediment entering the Chesapeake Bay (known as the TMDL). Because cover crops reduce wind and water erosion and use up residual soil nutrients, they reduce the amount of nutrients reaching streams, rivers, and—eventually—the Bay. In 2004, the program paid \$20 per acre to farmers willing to plant a cover crop but enrolled only 113,522 acres. With additional funding, the State increased the minimum payment from \$20 per acre to \$45 per acre, and the program grew to 475,560 acres in 2015. These cover crop acres planted in 2015 prevented an estimated 2.85 million pounds of nitrogen and 95,000 pounds of phosphorus from reaching Maryland waterways. The Maryland example suggests that many farmers are willing to adopt cover crops with a large enough financial incentive.

Farmers With Oat and Cotton Fields Measure the Health of Their Soil

New data from the field-level, commodity-specific versions of USDA’s 2015 USDA Agricultural Resource Management Survey suggest that some farmers are measuring for a key soil health indicator: soil organic matter (SOM). The survey asked farmers with an oat or cotton field if they had tested their SOM in the past 10 years, and if they had, what the percentage of SOM was the last time they tested. For those who had tested more than once, the survey asked whether their SOM was increasing, decreasing, or staying roughly the same.

An estimated 15.8 percent of cotton fields and 11.0 percent of oat fields were tested for SOM at least once in the last 10 years. For cotton fields, the majority of farmers who tested more than once reported that their SOM was staying roughly the same. Among oat farmers, roughly equal proportions reported that the SOM on their fields was increasing versus staying the same. Few farmers, for both crops, reported decreasing SOM.

Just because farmers test for SOM does not mean they manage for all aspects of soil health, but it might suggest they believe there are private benefits associated with SOM. Fields that were not tilled or were tilled using conservation tillage in the survey year are more than twice as likely to be testing for SOM relative to fields that were conventionally tilled. With cover crops, the relationship is not as clear. Cotton fields that were cover cropped are more likely to have been tested for SOM, though there is no statistical evidence that oat fields that were cover cropped are any more or less likely than conventionally tilled oat fields to have been tested.

This article is drawn from...

Economics of Soil Health, Summary of ERS/Farm Foundation workshop and associated presentations on September 21 and 22, 2015, Farm Foundation

You may also be interested in...

Building Soils for Better Crops, 3rd Edition, Sustainable Agriculture Research and Education, 2010

Conservation-Practice Adoption Rates Vary Widely by Crop and Region, by Tara Wade, Roger Claassen, and Steven Wallander, USDA, Economic Research Service, December 2015

Comprehensive Assessment of Soil Health—The Cornell Framework Manual, Cornell University, 2016

"Healthy Soils Are..." fact sheets, USDA, Natural Resources Conservation Service, 2013

Soil Health Key Points, USDA, Natural Resources Conservation Service, August 2013

Sustainability Grows in Healthy Soil, USDA, Natural Resources Conservation Service, 2014

Soil Health, USDA, Natural Resources Conservation Service, May 2014

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