SOIL AND WATER CONSERVATION: AN ANNOTATED BIBLIOGRAPHY



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CHAPTER OVERVIEW

1: History and Fundamentals

1.1: Introduction
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1.1: Introduction

Abbreviations

FAO – Food and Agriculture Organization of the United Nations
NRCS – Natural Resources Conservation Service
SWCS – Soil and Water Conservation Society
US – United States
USDA – US Department of Agriculture

Soils and Agriculture



A soilscape showing the Cecil soil series (left) and the landscape in which it exists (right) in the North Carolina Piedmont. Photos by John Kelley, USDA NRCS, and courtesy of SoilScience.info.

Parikh, S. J., and B. R. James. 2012. "Soil: The Foundation of Agriculture." Nature Education Knowledge 3 (10): 2. https://www.nature.com/scitable/knowledge/library/soil-the-foundation-of-agriculture-84224268.

> This article introduces the crucial role soils play in agriculture. Soil is the primary source of plant nutrients and organic matter. Although agriculture supports life, it also disrupts natural ecosystem processes. Conventional agricultural practices have increased rates of soil erosion, highlighting the need for sustainable soil management as part of agricultural processes.

World History of Agriculture, Erosion, and Conservation

Brevik, Eric C. 2014. "Soil Science: Selected Historical Highlights in Celebration of the Upcoming International Year of Soils." Soil Horizons 55 (6). https://doi.org/10.2136/sh2014-55-6-gc.

> This short article briefly reviews highlights in the history of soil science in the US, including aspects of soil survey, soil geomorphology, soil erosion, and tools used in soil science, all of which apply to soil management. It also briefly introduces soil and human health connections, an area where soil management and conservation is very important.

Callaway, Shelby. 2018. "A Warning from Vanished Civilizations." SlideShare presented at the 2018 SWCS International Annual Conference, July 31. https://www.slideshare.net/SWCSevents/a-warning-from-vanished-civilizations.

> This SlideShare is a presentation from the SWCS meeting that includes pictures from some of Lowdermilk's travels (see Lowdermilk 1999 below) for the "Conquest of the Land Through 7,000 years" and summarizes why Lowdermilk's work is so important even to this day. The photographs provide context to Lowdermilk's work, showing some of the diverse environmental settings and cultures within which he conducted his investigation into soil cultivation and the resulting success or failure of the civilizations supported.

Lowdermilk, W.C. 1999. Conquest of the Land Through 7,000 Years. Agriculture Information Bulletin 99. Washington, D.C.: USDA NRCS. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=109.

> This NRCS bulletin is a first-hand account of Walter Lowdermilk's observations during his world travels to investigate the effects of hundreds or thousands of years of cultivation on land. His objective was to learn from the experience of these older civilizations and search for solutions to soil erosion and land use problems facing the US. He observed that soil erosion can be significant enough to topple empires, while conservation practices helped sustain other civilizations for centuries. The bulletin was originally printed in 1953 and later reprinted in 1994 without change. Lowdermilk was the former assistant chief of the Soil Conservation Service, now called the USDA NRCS.



The ruins of an ancient Roman city, Timgad. This photo by Lowdermilk was featured in his bulletin, The Conquest of the Land Through 7,000 Years (1999).

Montgomery, David R. 2007. “Soil Erosion and Agricultural Sustainability.” Proceedings of the National Academy of Sciences 104 (33): 13268–72. https://doi.org/10.1073/pnas.0611508104.

Conventional agriculture accelerates soil erosion rates. Soil erosion rates from agriculture are much higher than soil formation rates and even long-term geological erosion. This article compiles data from a number of global studies to determine the rates of soil erosion due to agricultural practices.

“Origins of Agriculture.” 2019. In Encyclopedia Britannica. Chicago, IL: Encyclopedia Britannica, inc. https://www.britannica.com/topic/agriculture.

This online encyclopedia article begins with a description of the range of definitions of agriculture and a description of the domestication of plants and animals. Techniques used for studying the origin of agriculture are then described, followed by a series of sections representing a timeline of agricultural history dating back to the dawn of agriculture at the end of the last ice age 11,700 years ago.

SWCS Events. 2019. The Lasting Legacy of Walter Lowdermilk’s Conquest of the Land Through 7,000 Years. Conservation Matters. Ankeny, IA: Soil and Water Conservation Society. https://vimeo.com/313261304.

This link is to an interview with Shelby Callaway. It provides additional insight and perspective for the materials in the Calloway (2018) presentation above and into the work of Walter Lowdermilk in the *Conquest of the Land Through 7,000 Years* (1999). This presentation is a good introduction to Lowdermilk’s seminal work.

USDA. 2000. “A Condensed History of American Agriculture 1776–1999.” USDA. https://www.usda.gov/sites/default/files/documents/history-american-agriculture.pdf.

This one-page document from the USDA is a timeline of agricultural history in the US from 1776 to 1999. Events noted in the timeline primarily include technological advances and changes in federal policy. Agricultural history related to native civilizations or the colonial period in North America are not included.

Inventory of Soil and Water Resources

FAO and ITPS. 2015a. “Chapter 3 – Global Soil Resources.” In Status of the World’s Soil Resources (SWSR) – Main Report. Rome, Italy: Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils. http://www.fao.org/global-soil-partnership/resources/highlights/detail/en/c/387547/.

This chapter from the *Status of the World’s Soil Resources* FAO report summarizes the condition of soils around the world. It begins with a brief overview of soil science concepts, including properties and mapping. It then details soil qualities critical for soil to deliver ecosystem services and the current status of those qualities worldwide. The chapter ends with an outline of efforts to assess global soil change. The link provided is a website that includes an outline and download links for every chapter of the *Status of the World’s Soil Resources* FAO report.

FAO and ITPS. 2015b. “Chapter 14 – Regional Assessment of Soil Changes in North America.” In Status of the World’s Soil Resources – Main Report. Rome, Italy: Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils. http://www.fao.org/global-soil-partnership/resources/highlights/detail/en/c/387547/.

This chapter from the *Status of the World’s Soil Resources* FAO report summarizes the soil resources of North America that, for this report, encompasses Canada and the US. The data sources for the report include Agri-Environmental Indicators report from Agriculture and Agri-Food Canada for Canada and the USDA National Resources Inventory for the US. The chapter first introduces and then describes the continent based on ecoregions. Soil threats like acidification, salinization, and compaction are described, followed by “major soil threats” like erosion, nutrient imbalances, organic carbon storage, and biodiversity. Canada was used as a case study in Section 14.5 to detail those threats to Canadian soils. The link provided is a website that includes an outline and download links for every chapter of the *Status of the World’s Soil Resources* FAO report.

USDA NRCS. 2018. “Summary Report: 2015 National Resources Inventory.” US Department of Agriculture. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/.

The 2015 National Resources Inventory summarizes a series of natural resource inventories conducted by the USDA NRCS. The report outlines the status, condition, and trends in soil, water, land, and related resources on non-federal lands in the US. The report is lengthy, 210 pages. However, each chapter contains many maps and summary tables to supplement the text. Chapter 2 provides highlights of the overall report. Additional chapters cover broad land cover and use, cropland and pastureland inventories, soil characteristics, wetlands, and methodology. The National Resources Inventory data is collected annually and summarized at 5-year intervals. The link provided is a website with download links for the full report, as well as summary reports focused on more specific topics, such as the National Resources Inventory wetlands data.

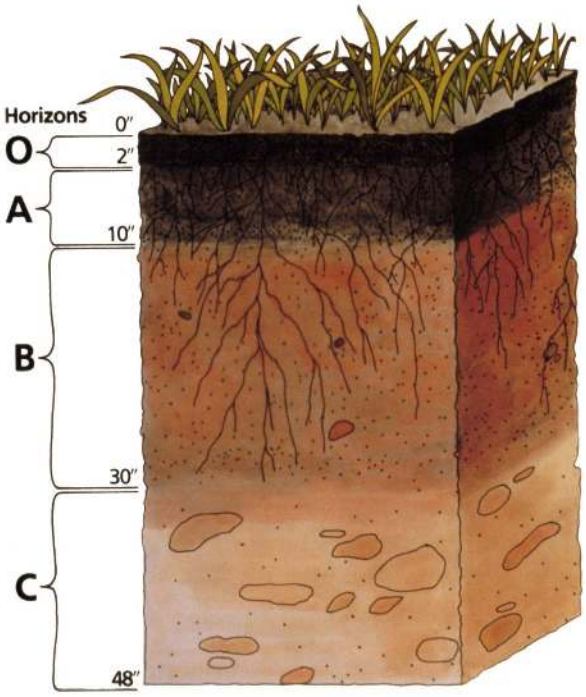
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1.2: Key Concepts in Soil Science

Abbreviations

NCCS – National Soil Survey Center
NCSS – National Cooperative Soil Survey
NRCS – Natural Resources Conservation Service
US – United States
USDA – US Department of Agriculture

Basic Concepts of Soil Science



A soil profile. Figure courtesy of the NRCS.

Ecological Society of America. 1997. “Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems.” 2. Issues in Ecology. Washington, D.C.: Ecological Society of America. https://www.esa.org/esa/wp-content/uploads/2013/03/issue2.pdf.

> Ecologists have long recognized and discussed ecosystem services, but soil science and other fields now recognize ecosystem services and widely discuss their importance. This article defines ecosystem services and describes the different types of services. The differences between services provided naturally contrast with technological services like engineering. Several examples of important ecosystem services are given, including those supplied by soils and those important to agriculture. Threats to ecosystem services and methods to assign a monetary value to them are also covered.

Ingham, Elaine R., Andrew R. Moldenke, and Clive A. Edwards. 2000. “Soil Biology Primer [Online].” USDA NRCS. Soil and Water Conservation Society, Ankeny, IA. 2000. https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/.

> Soil supports life, and a number of biological organisms (macro- and micro-organisms) are found in the soil. This USDA NRCS web page, also available in print, describes various biological groups found in soils and their role in maintaining soil fertility. The “*food web*” sections describe predator-prey and feeding interactions among organisms. The *bacteria* and *fungi* sections focus on microorganisms that decompose organic matter and help maintain nutrient levels in soils. *Nematodes* feed on microorganisms and *arthropods* chew and shred leaf matter that bacteria and fungi then decompose. *Earthworms* chew and decompose organic matter and mix the soil, among other functions.

McCauley, Ann, Clain Jones, and Jeff Jacobsen. 2005. “Module I – Basic Soil Properties 4481-1.” In Soil and Water Management, 12. 4481-1. Bozeman, MT: Montana State University. http://landresources.montana.edu/swm/.

In this chapter of a five-chapter self-study course at Montana State University, the authors discuss how soil physical properties like texture and structure influence water retention and chemical properties of the soil. Chemical properties include cation and anion exchange, pH and acidity, and salinity. How carbonates affect soil physical and chemical properties is also described. The chapter concludes by discussing how soil organic matter and soil organisms influence a wide range of basic soil properties.

Needelman, B. A. 2013. “What Are Soils.” Nature Education Knowledge 4 (3): 2. https://www.nature.com/scitable/knowledge/library/what-are-soils-67647639.

This article from the Nature Education Project introduces readers to the diversity of soils, particularly their composition, visual appearance, nutrient availability, and ecosystem services and benefits. Needleman describes soil composition using five ingredients: minerals, soil organic matter, living organisms, gas, and water. He also describes them as natural bodies that differ in visual appearance (colors, horizons, and layers), availability of plant nutrients, and ecosystem services and benefits.

O’Geen, A. T. 2012. “Soil Water Dynamics.” Nature Education Knowledge 3 (6): 12. https://www.nature.com/scitable/knowledge/library/soil-water-dynamics-103089121.

The sustainability of water quality and quantity is directly influenced by soil. Thus, most aspects of terrestrial and freshwater aquatic life depend on hydrologic processes in soil. This article from the Nature Education Knowledge Project focuses on soil water dynamics and introduces concepts of soil moisture storage, water flow, and the soil properties that influence these processes. O’Geen provides an introduction to the soil water balance equation, describes the factors and soil properties that govern water potential and plant available water holding capacity, and soil morphologic features and classification methods to describe the fate of water in soil.

Peterson, J. M. Ed. 2019. Soils – Part 2: Physical Properties of Soil and Soil Water. https://passel2.unl.edu/view/lesson/0cff7943f577.

This web page from the Plant and Soil Sciences eLibrary describes the physical composition of soil (solids, liquids, and gases) and basic physical properties. Those physical properties include soil texture and particle size, structure, particle density, bulk density, and porosity. The web page concludes by showing the context for these physical properties in soil profiles and soil classification.

Scheyer, J.M., and K.W. Hipple. 2005. Urban Soil Primer. Lincoln, NE: US Department of Agriculture Natural Resource Conservation Service. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=479.

The Urban Soil Primer is intended to give planning officials and people who live in urban areas an introduction to soils. It provides information important for planning and managing land resources to help prevent or mitigate problems associated with sedimentation, contamination, runoff, and structural failure. This publication describes in nontechnical language the basic processes and functions common to all soils.

USDA NRCS. 2011. “Chapter 4 Elementary Soil Engineering.” In Engineering Field Handbook, 99. 210–VI–EFH. Washington, D.C.: USDA NRCS. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17543.wba.

The Soil Conservation Service (now USDA NRCS) provides technical assistance for using soil as a building material or as support for buildings and infrastructure. This chapter from the USDA NRCS Engineering Field Handbook outlines the fundamentals of soil engineering, which apply the physical, chemical, and mechanical properties of soil to their use as a construction material and as a foundation for structures. Fundamental soil engineering topics covered include the basic soil concepts that relate to engineering; an engineering classification and description system for soil; and guides for estimating soil strength, permeability, erosion resistance, and other performance characteristics. Site investigations and procedures for embankment design of earth dams are also discussed.

"Chapter 3, Soil Water." 2018. Plant and Soil Sciences ELibrary. 2018. http://croptechnology.unl.edu/pages/informationmodule.php?idinformationmodule=1130447123&topicorder=3&maxto=73&minto=1.

Soil water is important in crop production and the movement of nutrients and contaminants through the near-surface environment. This article provides a basic overview of soil water concepts and the fundamental soil properties that control soil water content and movement. This web page begins by defining types of soil water and the tensions at which the water is held in the soil. Available water holding capacity, infiltration, and water movement are then briefly described.

USDA NRCS. 1996a. "Soil Quality Indicators: Aggregate Stability." Soil Quality Information Sheet. Lincoln, NE: US USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=386.

Soil quality is generally defined as the capacity of a soil to function for a specific purpose. Various indicators are used to assess soil quality. This USDA NRCS fact sheet summarizes one such indicator: aggregate stability. The information sheet also summarizes the relationship between soil quality and soil function, improving soil aggregate stability, and methods for assessing soil aggregates.

USDA NRCS. 1996b. "Soil Quality Indicators: Soil Crusts." Soil Quality Information Sheet. Lincoln, NE: USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=387.

Soil quality is generally defined as the capacity of a soil to function for a specific purpose. This USDA NRCS fact sheet summarizes soil crusts as an adverse effect of declining soil quality. This document summarizes inherent and dynamic soil properties that influence soil crusting, the relationship to soil function, methods for avoiding soil crusting, and methods for measuring soil crusting.

USDA NRCS. 1996c. "Soil Quality Resource Concerns: Sediment Deposition." Soil Quality Information Sheet. Lincoln, NE: USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=388.

In this soil quality information sheet, the USDA NRCS defines sediment as solid material that has been moved by air, water, gravity, or ice from its original location to a field or low landscape position. Sediment, when deposited on agricultural fields, can cause major problems for crop or forage production. The NRCS goes on to describe the effect of sediment deposition on soil quality, how to identify sediment, and what can be done about sediment.

USDA NRCS. 1998a. "Soil Quality Resource Concerns: Soil Erosion." Soil Quality Information Sheet. Lincoln, NE: USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=391.

Erosion is one of the major threats to soil quality. This USDA NRCS information sheet describes why erosion is a problem, signs that indicate erosion, ways to quantify erosion, and conservation practices that can limit erosion. Both wind and water erosion are discussed.

USDA NRCS. 1998b. "Soil Quality Indicators: Infiltration." Soil Quality Information Sheet. Lincoln, NE: USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=397.

Water can only be used by crops if it infiltrates the soil. Water that runs off the soil surface is not available to the soil environment or the plants growing in the soil. Therefore, infiltration is critical for water availability and overall soil function. In this information sheet, the USDA NRCS defines infiltration and describes the factors that affect infiltration rates, why low infiltration rates are generally not desirable, ways to improve infiltration, and a simple way to measure infiltration.

USDA NRCS. 1998c. "Soil Quality Indicators: Soil pH." Soil Quality Information Sheet. Lincoln, NE: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs142p2_052474&ext=pdf.

Soil pH is a soil master variable that influences nutrient availability, microbial communities, and many other soil properties. This USDA NRCS information sheet defines soil pH, explaining why it is important, what affects soil pH, a common and simple way to measure soil pH, and how to modify soil pH.

USDA NRCS. 1998d. “Soil Quality Resource Concerns: Soil Biodiversity.” Soil Quality Information Sheet. Lincoln, NE: USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=414.

In this USDA NRCS soil quality information sheet, the USDA NRCS defines soil biodiversity and describes the benefits of soil organisms as well as management techniques that promote soil biodiversity. It includes a diagram that simplifies soil biodiversity as a concept and groups soil organisms by trophic levels.

USDA NRCS. 1998e. “Soil Quality Resource Concerns: Salinization.” Soil Quality Information Sheet. Lincoln, NE: USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=392.

In this soil quality information sheet, the USDA NRCS defines salinization as the process by which salts accumulate in the soil. The USDA NRCS then describes the causes and indicators of salinization, the effects of salinity, and how salinity can be managed.

USDA NRCS. 2001a. Guidelines for Soil Quality Assessment in Conservation Planning. 48. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/assessment/.

In this guide for soil quality assessment in conservation planning, the USDA NRCS describes their conservation planning process, introduces the concepts of soil quality, and describes how to collect and analyze information to assess soil quality. The guide also includes a list of additional resources. This guide can be used as a planning guide for informal assessments or for quick assessment of soil quality.

USDA NRCS. 2001b. “Soil Health Assessment.” Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/assessment/.

The terms soil health and soil quality are often used synonymously, as on this USDA NRCS web page. On this page, the USDA NRCS describes the concept of soil health and provides links to downloads of soil quality indicator sheets. They state that measurements of soil quality are only useful if the indicators measure changes in soil function; encompass chemical, biological, and physical properties; are accessible to many users under applicable field conditions; and are sensitive to variations in management and climate. The relationship of soil quality indicators to soil health is briefly explained with examples. The web page then concludes by describing and linking to another document: “Guidelines for Soil Quality Assessment in Conservation Planning.”

USDA NRCS. 2001c. “Rangeland Soil Quality – Organic Matter.” Soil Quality Information Sheet 6. Rangeland Soil Quality. Lincoln, NE: US Department of Agriculture. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=384.

In this soil quality information sheet, the USDA NRCS describes the importance of soil organic matter to rangeland soil quality. In the guide, the USDA NRCS defines soil organic matter, why it is so important to our soils, what affects organic matter, and how to maintain optimum soil organic matter content. While the focus of the information sheet is rangeland soils, the general principles apply to a wide range of land uses and soil management strategies.

USDA NRCS. 2001d. “Soil Quality – Introduction.” Soil Quality Information Sheet. USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052207.pdf.

The USDA NRCS begins this soil quality information sheet by defining soil and describing what it does for human civilization. The USDA NRCS then describes soil quality, why it is important, and how to evaluate it. The sheet ends by briefly discussing soil quality issues that can cause problems, and refers readers to additional soil quality information sheets that discuss each of these issues individually.

USDA NRCS. 2003. “Managing Soil Organic Matter: The Key to Air and Water Quality.” Soil Quality Technical Note No. 5. USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=398.

This technical note from the USDA NRCS Soil Quality Institute focuses on managing soil organic matter. The note begins by explaining why erosion control alone is not enough to conserve soil and the rationale for focusing on soil organic matter. The Soil Quality Institute also describes why soils should be managed for carbon, not just keeping erosion at a tolerable annual rate. The note concludes with an overview of those soil properties influenced by soil organic matter and what soil managers can do to manage for carbon.



Granular soil structure, indicative of high amounts of soil organic matter and significant amounts of biological activity. Photographs by John Kelley, courtesy of the USDA NRCS.

Soil Health

Al-Kaisi, Mahdi, and David Kwaw-Mensah. 2017. “Iowa Soil Health Management Manual.” Extension Publication CROP 3090A. Ames: Iowa State University Extension and Outreach. https://store.extension.iastate.edu/product/Iowa-Soil-Health-Management-Manual.

This Iowa State University extension publication centers on appropriate soil management and how that leads to sustainable agricultural systems. It begins by explaining the fundamentals of soil science essential for appropriate soil management and then defines soil health and explains why that is important. This is followed by chapters that cover management practices that build soil health and how to evaluate the health of a soil.

USDA NRCS. 2018a. “Healthy Soils Are Full of Life.” USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=1023.

The abundance of life present in a healthy soil is the focus of this USDA NRCS information sheet. It includes a brief discussion of what farmers can do to build a soil ecosystem with abundant and diverse organisms and explains the fundamental function of each major non-plant organismal group found in soil.

USDA NRCS. 2018b. “Healthy Soils Are High in Organic Matter.” USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=1024.

This USDA NRCS information sheet provides perspective on the importance of soil organic matter. It includes information on the role of soil organic matter in the soil system, how inappropriate management can reduce soil organic matter, how increase soil organic matter, and the differences between active and stabilized soil organic matter.

USDA NRCS. 2018c. “Healthy Soils Are Well Structured.” USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=1025.

In this information sheet, the USDA NRCS defines soil structure and identifies what is important in building good structure. The information sheet also describes how certain activities destroy structure and a simple test for stable structure in soil.

USDA NRCS. 2018d. “Soil Health Key Points.” USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=1027.

This USDA NRCS information sheet describes why soil health is important and lists the benefits of healthy soil. It then lists four basic principles to improve soil health, discussing how a soil health management plan can help farmers improve soil health.

Soil Survey

O’Geen, T. 2018a. “SoilWeb: An Online Soil Survey Browser.” California Soil Resource Lab. 2018. https://casoilresource.lawr.ucdavis.edu/gmap/.

SoilWeb is maintained at the University of California Davis and allows users to explore soil survey data for the US through a web application on most internet browsers. SoilWeb is a useful resource in the field, because it queries GPS-referenced soils data from the National Cooperative Soil Survey (NCSS) and displays the soil survey polygons over aerial imagery.

O'Geen, T. 2018b. SoilWeb Earth. Google Earth. Davis, CA: California Soil Resource Lab. https://casoilresource.lawr.ucdavis.edu/soilweb-apps/.

SoilWeb Earth delivers soil survey data in keyhole markup language (KML) file format, which allows the soil data to be displayed across a three-dimensional landscape if Google Earth or another means is used to display KML files. This is a useful way to visualize soil mapping units across landscapes while still using the same data source as the Web Soil Survey.

Soil Survey Staff, NRCS, K. Scheffe, and S. McVay. 2017. "Chapter 4. Soil Mapping Concepts." In Soil Survey Manual, 235–94. USDA Handbook 18. Washington, D.C.: Government Printing Office. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054254.

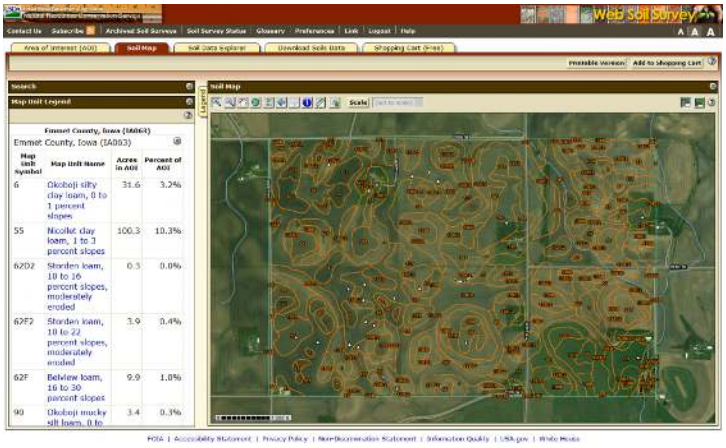
Soil mapping is the process of delineating natural bodies of soils, classifying and grouping the delineated soils into map units, and capturing soil property information for interpreting and depicting soil spatial distribution on a map. In this chapter, the soil survey staff present the steps for soil mapping, classification, and correlation, followed by quality control and quality assurance of soil survey information. Soil maps made using other methods are presented at the end of the chapter.

Soil Survey Staff, NRCS, C. Ditzler, and L. West. 2017. "Chapter 1. Soil and Soil Survey." In Soil Survey Manual, 1–20. USDA Handbook 18. Washington, D.C.: Government Printing Office. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054251.

In this chapter, the soil survey staff define the term soil survey within the context of the NCSS in the US. They discuss the development of pedology (the study of soils in their natural setting) and the important concept of soils as natural three-dimensional bodies that form as a result of the interaction of five soil-forming factors. They state that the repeating patterns formed by these natural bodies of soil in the landscape allow soil scientists to develop predictive soil-landscape models, which serve as the scientific foundation for making soil surveys. The chapter concludes with important milestones in the development of the Soil Survey in the US.

Soil Survey Staff, USDA NRCS. 2018. "Web Soil Survey." USDA NRCS. 2018. https://websoilsurvey.sc.egov.usda.gov/.

The Web Soil Survey is a simple to use web application that provides soil survey information to end users. This information includes customized soil maps, soil data, and interpretive soil maps for 95% of the counties in the US. The Web Soil Survey is an important tool that can be used in soil management at the field scale.



A screenshot of the Web Soil Survey web app. Screenshot by Colby Moorberg.

USDA NRCS. 2010. From the Surface Down: An Introduction to Soil Surveys for Agronomic Use. Second. Lincoln, NE: USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=449.

This publication should increase user understanding of soils and the content of soil surveys as well as supplemental interpretations important to agronomic programs. Proficiency in using soil survey data requires a basic understanding of the concepts of soil development and of soil-landscape relationships. The first three sections cover these basic concepts. The last five sections cover soil survey information and where to find information on soil properties.

USDA NRCS NSSC. 2018a. Web Soil Survey – Part 1: Application Access (2/2018). Lincoln, NE: USDA NRCS NSSC. https://www.youtube.com/watch?v=vxSW49ZK8vM.

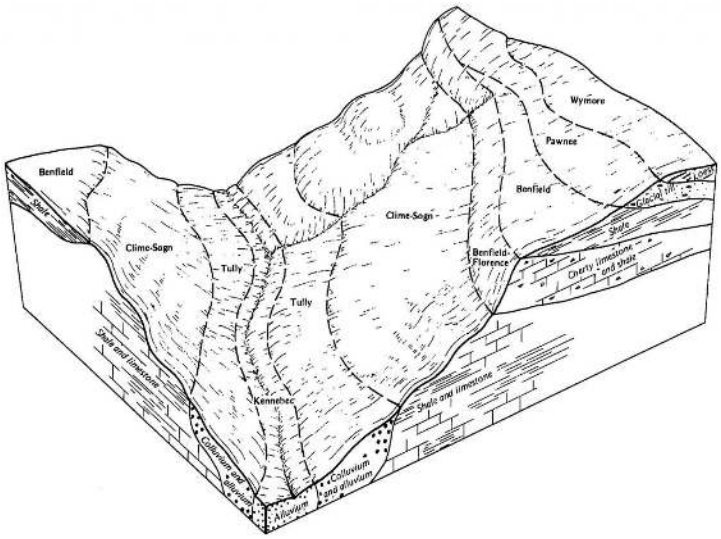
This NRCS video is the first in a series of YouTube videos that explains how to use the Web Soil Survey. This video focuses on basic navigation from the Web Soil Survey homepage.

USDA NRCS NSSC. 2018b. Web Soil Survey – Part 2: Set Area of Interests (2/2018). Lincoln, NE: USDA NRCS NSSC. https://www.youtube.com/watch?v=bciIQrk3bjs.

This is Part 2 of the Web Soil Survey YouTube video tutorials. In it, the USDA NRCS presents how to use the Web Soil Survey . This video focuses on how to define an area of interest to create a customized soil report. The limitations in creating these custom reports are also discussed.

USDA NRCS NSSC. 2018c. Web Soil Survey – Part 3: Tabs and Downloads (2/2018). Lincoln, NE: USDA NRCS NSSC. https://www.youtube.com/watch?v=thWicmr1tp0.

This is Part 3 of the Web Soil Survey YouTube video tutorials. This tutorial focuses on how to download information, including soil data, for an area of interest for which users have created a custom soil map.



A soil block diagram depicting the pattern of soils and parent material in the Clime-Tully-Benfield association. Figure courtesy of the Soil Conservation Service (now the USDA NRCS).

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1.3: Soil Erosion Processes

Abbreviations

- ARS – Agriculture Research Service
- ASA – American Society of Agronomy
- CSSA – Crop Science Society of America
- EPA – US Environmental Protection Agency
- PDF – Portable Document Format
- RUSLE – Revised Universal Soil Loss Equation
- SSSA – Soil Science Society of America
- URL – Uniform Resource Locator
- US – United States
- USDA – US Department of Agriculture
- USLE – Universal Soil Loss Equation
- WEPP – Water Erosion Prediction Project
- WEPS – Wind Erosion Prediction System
- WEQ – Wind Erosion Equation

Coastal Erosion



Beach erosion at the Outer Banks of North Carolina. Photograph by David Crouse, courtesy of SoilScience.info.

National Research Council. 2007. “Chapter 2 Understanding Erosion on Sheltered Shores.” In Mitigating Shore Erosion Along Sheltered Coasts, 25–43. Washington, D.C.: The National Academies Press. https://doi.org/10.17226/11764.

> This book chapter from the National Research Council includes information on the fundamentals of shoreline erosion. The chapter has three sections: “The Physics of Coastal Erosion,” “Spatially and Temporally Variable Factors Controlling Coastal Erosion,” and “Implications of Geomorphic Settings for Erosion Mitigation Strategies.”

Short, A. D. 2012. “Coastal Processes and Beaches.” Nature Education Knowledge 3 (10): 15. https://www.nature.com/scitable/knowledge/library/coastal-processes-and-beaches-26276621.

> This Nature Education Knowledge Project web page uses an encyclopedia-style approach to convey concepts of coastal processes and beaches. Short provides concise summaries of major coastal processes, including wave generation and types, tides and tidal currents, wind and currents, sea level, and overviews of beach systems, beach sediment types and sources, beach subsystems, beach types, and barriers. This web page includes many relevant and useful photographs and figures, as well as additional reading.

Sloss, C. R., M. Shepherd, and P. Hesp. 2012. “Coastal Dunes: Geomorphology.” Nature Education Knowledge 3 (10): 2. https://www.nature.com/scitable/knowledge/library/coastal-dunes-geomorphology-25822000.

This Nature Education Knowledge Project web page uses an encyclopedia-style approach to describe coastal dunes. Sloss begins with an explanation of the classification of coastal dunes and explains primary dunes and secondary dunes. Primary dunes are the result of accumulated beach sediment. Over time, primary dunes are increasingly influenced by vegetation as they become isolated from the beach. Types of primary dunes include incipient, established, and relict foredunes. Eventually primary dunes become so cut off from the sediment supply and prevailing erosional processes from the beach that secondary dunes form. Secondary dunes include blowouts, parabolic dunes, and transgressive sand sheets and dunefields. Photographs and diagrams provide visual examples of each dune type. The webpage has references and recommended readings at the end.

Streambank Erosion



Streambank erosion along a stream in Iowa. Photograph by Lynn Betts, courtesy of the USDA NRCS.

Burnette, Matthew C., and Carmen T. Agouridis. 2014. “Streambank Erosion.” Extension Publication AEN-124. Lexington, KY: University of Kentucky. http://www.ca.uky.edu/agc/pubs/aen/aen124/aen124.pdf.

In this extension publication from the University of Kentucky, Burnette and Agouridis define streambank erosion, identify its causes, and explain why it is problematic. Then, they describe practices used to minimize streambank erosion and list relevant considerations for implementing these practices. Streambank erosion was identified as a source of concern because it leads to aquatic habitat destruction, loss of agricultural land, and safety issues. Among the methods to reduce streambank erosion are increasing stream access to the floodplain, reshaping the stream channel to direct flow away from the banks, and populating streambanks with deep-rooted riparian vegetation.

EPA Office of Water. 2007a. “Chapter 5: Streambank and Shoreline Erosion.” In National Management Measures to Control Nonpoint Source Pollution from Hydromodification, 5.1-9. EPA 841-B-07-002. Washington, D.C.: US EPA. https://www.epa.gov/nps/hydromodification-and-habitat-alteration-national-management-measures.

This chapter on streambank and shoreline erosion is in the EPA’s book, *National Management Measures to Control Nonpoint Source Pollution from Hydromodification*, a book intended to help assist states, tribes, and the public reduce nonpoint source pollution of surface and groundwater. Streambank erosion is a source of nonpoint source pollution with sediment and sediment-bound contaminants. The EPA lists and explains human activities that change stream characteristics, hydraulics, and/or morphology that ultimately contribute to streambank erosion. In this chapter, the EPA states that to stabilize streambanks, either vegetation or engineered structures may be used, noting further that the level of streambank exposure to severe erosional forces determines the method of stabilization. The EPA goes on to list tips and provide guidance in properly constructing and implementing stabilization structures and practices, including site preparation, practices to avoid, and maintaining structures or practices.

EPA Office of Water. 2007b. “Chapter 8: Modeling Information.” In National Management Measures to Control Nonpoint Source Pollution from Hydromodification, 8.1-19. EPA 841-B-07-002. Washington, D.C.: EPA. https://www.epa.gov/nps/hydromodification-and-habitat-alteration-national-management-measures.

This chapter from the EPA’s book, *National Management Measures to Control Nonpoint Source Pollution from Hydromodification*, contains descriptions of models that simulate and predict the effects of hydraulic and hydrologic changes on streams. The chapter includes two tables: one that describes models, and the other describes how to decide which model is most appropriate. The overall aim of the book is to assist states, tribes, and the public in reducing nonpoint source pollution of surface and groundwater. This chapter can be used to determine which model is most appropriate for making decisions related to reducing nonpoint source pollution from streambank erosion.

Wampler, P. J. 2012. “Rivers and Streams-Water and Sediment in Motion.” Nature Education Knowledge 3 (10): 18. https://www.nature.com/scitable/knowledge/library/rivers-and-streams-water-and-26405398.

This Nature Education Knowledge Project web page uses an encyclopedia style to convey concepts of water and sediment transport in rivers and streams. Sources are cited extensively, making the website a useful resource for additional readings and further exploring the topic. The page does contain a few images, though more figures and photographs would help communicate more effectively. In this page, Wampler describes how rivers are valuable to human civilization and the natural world, but also explains how human activities such as damming can disrupt a river’s capacity to provide ecosystem services. Wampler further states that such disturbances can be irreversible, and that restoration should rely on mimicry and soft structure rather than hydraulic engineering. Further, indicators like bed composition and channel slope can help in setting goals for improvement.

Water Erosion



Severe rill and sheet erosion on highly erodible soils in Cass County, Iowa. Photograph by Lynn Betts, courtesy of the USDA NRCS.

Flanagan, Dennis C., John E. Gilley, and Thomas G. Franti. 2007. “Water Erosion Prediction Project (WEPP): Development History, Model Capabilities, and Future Enhancements.” Biological Systems Engineering: Papers and Publications, July. http://digitalcommons.unl.edu/biosysengfacpub/27.

In this peer-reviewed journal article, the authors document a detailed history of the development of the WEPP model, identify new modeling efforts at the time of publication, and comment on the impact and legacy of the model. The computer-based WEPP model has been substantially improved since its inception in 1985, leading to the current model capabilities for predicting water erosion as documented in this article.

Jones, A. J., D. Walters, W. G. Hance, E. C. Dickey, and J. R. Culver. 1988. “Universal Soil Loss Equation: A Handbook for Nebraska Producers.” EC88-116. Lincoln: Nebraska Cooperative Extension Service. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2620&context=extensionhist.

This 23-page extension bulletin from the University of Nebraska is a step-by-step guide to estimating erosion rates using the USLE. The target audience is Nebraska farmers although the information is applicable to other regions of the US, assuming soil K-factors and erosivity (R) values are available. The USLE model is a multiplicative model, meaning all factors are multiplied together. For the USLE model, the resulting product is the rate of soil erosion in units of tons per acre. This extension publication is dated, and the USLE is no longer supported or used by the NRCS. However, the concepts conveyed in this model make predicting soil erosion rates with the USLE a useful educational exercise.

Moorberg, Colby, and David Crouse. 2017. "Laboratory 8 – Soil and Water Conservation." In Soils Laboratory Manual, K-State Edition, 66–76. Manhattan, KS: New Prairie Press. http://newprairiepress.org/ebooks/15.

This source is a laboratory exercise written for college students enrolled in introductory soil science courses. Students completing this exercise should be able to identify the conditions under which soil is most susceptible to wind and water erosion, estimate erosion rates using RUSLE, understand tolerable erosion rates known as T values, describe soil conservation practices, and identify agencies relevant to soil and water conservation. The laboratory activities include watching educational videos, completing calculations using RUSLE, and interpreting calculation results.

Ritter, J. 2012. Soil Erosion – Causes and Effects. Ontario Ministry of Agriculture, Food, and Rural Affairs. http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm.

This "factsheet" from the Ontario Ministry for Food, Agriculture, and Rural Affairs provides an overview of types of soil erosion. The bulletin outlines water erosion as well as other types of soil erosion, including streambank, wind, and tillage erosion. The bulletin outlines factors that influence soil erosion from water, including rainfall and runoff intensity, soil erodibility, cropping and vegetation, slope length and gradient, and tillage practices. The resources is available in web page format, or available as a downloadable PDF.

USDA ARS. 2016. "USLE History." USDA ARS. August 12, 2016. https://www.ars.usda.gov/midwest-area/west-lafayette-in/national-soil-erosion-research/docs/usle-database/usle-history/.

This ARS web page presents the history of the USLE. The USLE is an empirical model developed to predict the annual rate of soil erosion. The web page begins with a general description of the USLE. This is followed by a history of soil erosion research in the US, a summary of federal conservation programs, and a concise history of the development of the USLE, including a timeline. The page also includes relevant historical photographs.

USDA ARS. 2017. "WEPP." USDA ARS National Soil Erosion Research Laboratory. October 2, 2017. https://www.ars.usda.gov/midwest-area/west-lafayette-in/national-soil-erosion-research/docs/wepp/.

The ARS in West Lafayette, IN, oversees WEPP programming and updates made available to the public on this webpage. This webpage is a list of links to resources related to the computer-based WEPP model. This includes a download page with earlier versions as well as the most recent version of WEPP, version 2012.8. Other resources like documentation, release notes, and climate generator files are also listed.

Wind Erosion



Dust Storm in Southwest Kansas.

officemmdivide. 2011. Wind Erosion. https://www.youtube.com/watch?v=PQmon7Rj6ns.

Both water and wind erosion are explained briefly in this short video from the Land Conservation Assistance Network, a 501(c)(3) nonprofit that helps landowners sustainably manage wetlands, forests, and farms. The video defines erosion and explains why it is undesirable. Erosion rates under extreme conditions are provided for both water and wind erosion, giving context to the magnitude of erosion. Wind erosion is described in more detail, including the three types of sediment transport in wind erosion, along with an explanation for how wind erosion begins.

Tatarko, J., W. Trujillo, and M. Schipanski. 2019. Wind Erosion Processes and Control. 20. Colorado State University Extension. http://www.logan.colostate.edu/agri/agri_docs/CSU-WindErosion-LoRes.pdf.

This extension bulletin from Colorado State University Wind summarizes the fundamentals of wind erosion. Wind erosion processes are described, as well as wind erosion control. Wind erosion processes discussed include wind, prevailing wind erosion direction, and the critical wind erosion period, as well as phases of sediment movement, and modes of sediment transport. Strategies for controlling wind erosion covered in this bulletin include vegetation and residues, permanent vegetative cover, surface roughness and aggregate stability, cross wind strip cropping, wind barriers, and emergency wind erosion control. Wind erosion models and research on wind erosion are also described.

Tatarko, J., L. Wagner, and F. Fox. 2019. The Wind Erosion Prediction System and its Use in Conservation Planning. In Bridging Among Disciplines by Synthesizing Soil and Plant Processes, 71–102. Madison, WI: ASA, CSSA, SSSA, Inc. https://www.ars.usda.gov/ARSUserFiles/24758/4.%20The%20Wind%20Erosion%20Prediction%20(002).pdf.

Wind erosion research was spearheaded by the USDA ARS following Dust Bowl. The empirical WEQ was established in 1965 and later replaced by WEPS to reflect recent research results and technological advances. This book chapter from *Bridging Among Disciplines by Synthesizing Soil and Plant Responses* includes a detailed description of the development of the WEPS model and documents the model structure and uses. WEPS has several uses: assisting land managers in reducing wind erosion, establishing soil loss tolerance in conservation plans, and determining erosion susceptibility of soils. The model operates using agricultural databases and user inputs to run a series of submodels, including hydrology, land management, soil type, plant growth, decomposition, and erosion. From this information, WEPS can simulate the effects of various conservation practices on erosion of soil by wind.

USDA NRCS. 2019. Archived Wind Erosion Equation (WEQ). https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/tools/weps/?cid=nrcs144p2_080201.

This archived website from the NRCS describes the factors that were part of the WEQ, which is no longer supported by the NRCS. As described on the site, the WEQ is a process-based model used to estimate wind erosion rates. It has since been replaced by the WEPS, though many WEQ processes were incorporated into WEPS. The website includes links to resources associated with the WEQ.

USDA NRCS. 2019. Wind Erosion (WEPS). https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/tools/weps/.

The primary tool used to predict wind erosion is WEPS, described on this website from the USDA NRCS. This website includes download links to the most recent version of the model, as well as supporting files and links to related websites and WEPS training materials. The USDA ARS leads development of the WEPS model and supporting research on erosion. The focus of this USDA NRCS web page is to deliver the model to USDA NRCS field offices for official uses.

USDA NRCS. 2019. Wind Erosion Training Reference Materials. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/tools/weps/?cid=nrcs144p2_080198.

This USDA NRCS website provides a list of URL links to training materials for the WEPS model. The list includes links to a paper by Tartarko et al. (1999), a user manual, a quick start guide, example model runs, guidance on modeling with strip cropping and wind barriers, and archived WEPS training materials.

Warren, A., T. Gill, and J. Stout. 2018, July 3. Bibliography of Aeolian Research. https://www.lbk.ars.usda.gov/wewc/biblio/bar.htm.

This website provides over 40,000 references to reports, papers, and other resources from 1646 to 2015 that address aeolian research, which the site defines as “the study of the detachment, transport, and deposition of sediments by wind.” The

citations are sorted by author.

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CHAPTER OVERVIEW

2: Conservation Practices

2.1: Conservation Practices for Farmland

2.2: Conservation Practices for Shorelines, Streams, and Wetlands

2.3: Conservation Practices for Forest, Range, and Wildlands

2.4: Conservation Practices for Construction Sites and Disturbed Areas

2.5: Rehabilitation of Problem Soils

2.6: Water Quantity and Quality Conservation

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2.1: Conservation Practices for Farmland

Abbreviations

NRCS – Natural Resources Conservation Service
PDF – Portable Document Format
SARE – Sustainable Agriculture Research and Extension
SWCS – Soil and Water Conservation Society
URL – Uniform Resource Locator
US – United States
USDA – US Department of Agriculture

Contour Buffer and Prairie Strips



Contour Buffer Strips in Iowa. Photograph by Lynn Betts, courtesy of the USDA NRCS.

de Kok-Mercado, O. 2019. Science-Based Trials of Rowcrops Integrated with Prairie Strips. https://www.nrem.iastate.edu/research/STRIPS/.

This website from Iowa State University describes the use of prairie strips planted using native species along contours in row crop fields. It features links to additional information, frequently asked questions, and a short video on prairie strips.

SWCS Events. 2018. Prairie Strips: Build Benefits Naturally. Ankeny, IA: SWCS. https://vimeo.com/291571298.

This three-minute video from the SWCS advocates prairie strips and features a personal anecdote from Larry Stone, a corn and soybean farmer in Iowa; Tim Youngquist, an Agricultural Specialist II from Iowa State University; and Lance Koch from the USFWS. In the video, the participants recommend dedicating 10% of the area of a farm to prairie strips. The effects on wildlife like pheasants and butterflies is briefly mentioned.

USDA NRCS. 2014. Contour Buffer Strips. Conservation Practice Standard 332. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_026249&ext=pdf.

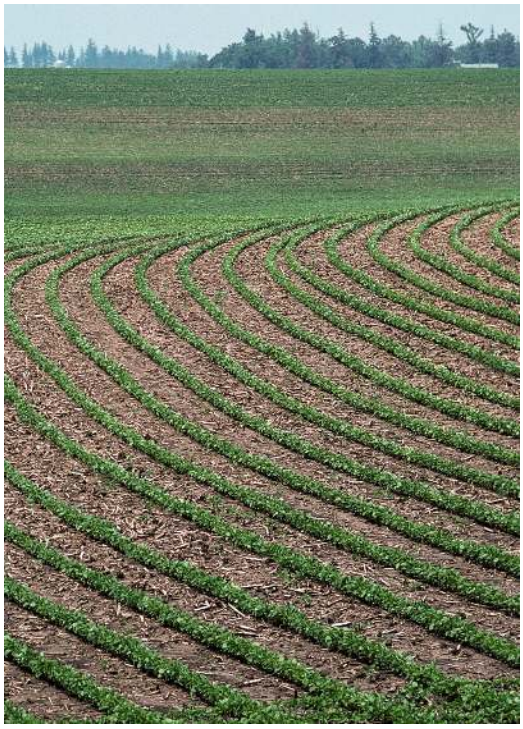
This conservation standard from the USDA NRCS defines contour buffer strips as narrow strips of permanent vegetative soil cover established along the contours of a hill slope, alternating with cropped strips farmed on the contour. The standard describes the purpose of this conservation practice, outlines conditions where the practice would apply, criteria for the practice, and some general considerations. It also briefly covers operation and maintenance of contour buffer strips. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2014b. Contour Buffer Strips. Conservation Practice Standard Overview 332. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263480.pdf.

This conservation practice standard overview for contour buffer strips from the USDA NRCS defines the practice. It also provides concise information about the practice. Commonly associated practices listed in this overview include grassed

waterways; integrated pest management; residue and tillage management, no-till, and reduced tillage. The URL offers a direct download of a PDF of this resource.

Contour Farming



Contour farming in northeast Iowa. Photograph by Lynn Betts, courtesy of the USDA NRCS.

The Editors of Encyclopedia Britannica. 2016, February 16. Contour Farming. Encyclopedia Britannica, Inc. https://www.britannica.com/topic/contour-farming.

This encyclopedia article from Encyclopedia Britannica briefly describes contour farming and the history and benefits of the practice.

USDA NRCS. 2017b. Contour Farming. Conservation Practice Standard 330. 3. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1335263&ext=pdf.

This conservation practice standard from the USDA NRCS defines contour farming as tillage, planting, and other operations aligned to the contour, creating roughness that alters the direction or velocity of water flow. The standard describes the purpose of the practice, general criteria for implementing the practice, considerations and other useful information. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2017a. Contour Farming. Conservation Practice Standard Overview 330. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_025663&ext=pdf.

This USDA NRCS overview of conservation practices provides a brief description and general information about contour farming. It contains a photograph of contour farming and a list of associated conservation practices, including grassed waterways, water and sediment control basins, and underground outlets. The URL leads to a direct download of a PDF of this publication.

Van Vlack, C. H., and L. E. Clapp. 1940. Contour Farming for Soil and Water Conservation. Bulletin P 1(11):1. https://lib.dr.iastate.edu/bulletinp/vol1/iss11/1/.

This historic extension bulletin from Iowa State University outlines the basics of contour farming. The bulletin outlines the effects of terracing, strip cropping, and contour farming on labor and fuel requirements, operating over terraces, and laying out guidelines for establishing contours.



An Iowa farmer using a roller crimper to terminate a cover crop and planting into the cover crop residue in the same pass. Photograph courtesy of the USDA NRCS.

Clark, A., ed. 2007. Managing Cover Crops Profitably. 3rd Edition. College Park, MD: SARE Program. https://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version.

This book, produced by SARE, provides in-depth information for nearly all aspects of cover crops as a conservation practice. Readers can navigate to an online version of each chapter in the book using the links on the left side of the screen. A printable PDF version of the book is also available. This book includes chapters on cover crop selection, rotations, soil fertility, pests, and more. Producer profiles are used throughout the book to provide real world scenarios and case studies for implementing cover crop in a production system. The book was designed to be a thorough resource, but not all encompassing, as was acknowledged in the foreword of the book.

Clark, A. 2019. Cover Crop Topic Room. https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops.

This website from SARE and the companion extension bulletin to the website (accessible through a link on the site) provide a thorough overview of cover cropping. Clark begins by defining cover crops as plants used to improve soil health, prevent erosion, enhance water availability, and more. Clark also discusses cover crop selection, management considerations, crop rotations, no-till farming, organic farming, economics, soil fertility, water management, pest management, and pollinators. The site features many hyperlinks for key topics, making it an excellent starting point for further reading on cover crops.

SWCS Events. 2018. Cover Crops: Improving Soils for Productivity and Profitability. Ankeny, IA: SWCS. https://vimeo.com/290520999.

This video from the Soil and Water Conservation Society features Doug Peterson, a soil health specialist with the USDA NRCS, along with testimonials from three different Iowa farmers who have implemented cover crops and no-till on their farms. The video focuses on the positives of cover crops and includes testimonies that highlight the positive effects that cover crops have had on farmers' lands.

USDA NRCS. 2014b. Cover Crop. Conservation Practice Standard 340. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263176.pdf.

This conservation practice standard from the USDA NRCS defines cover crops as legumes, grasses, and forbs planted to maintain seasonal vegetative cover. Cover crops are identified that reduce soil erosion, increase organic matter and soil health, improve water quality, suppress weeds, improve soil moisture use, and minimize soil compaction. The standard provides criteria and considerations for implementing cover crops, information for developing plans and specifications, and recommendations for operation and maintenance. The URL has a link for a direct download of a PDF of this resource.

USDA NRCS. 2014a. Cover Crop. Conservation Practice Standard Overview 340. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263481.pdf.

This conservation practice standard overview from the USDA NRCS begins with a definition of cover crops, followed by a brief description of the conservation practice. It concludes with a list of practices commonly associated with cover crops, including conservation crop rotation, residue and tillage management, nutrient management, and integrated pest management. The URL provides a direct link for a PDF of this resource.

Cross Wind Trap Strips



Cross wind trap strips used to trap saltating particles in erosion prone fields. Photograph courtesy of the USDA NRCS.

USDA NRCS. 2005. Cross Wind Trap Strips. Conservation Practice Standard 589C. 3. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263186.pdf.

This conservation practice standard from the USDA NRCS defines cross wind trap strips as herbaceous cover established in strips perpendicular to the most erosive wind events. The standard provides information on where the practice applies, criteria for implementing the practice, general considerations, and plans and specifications. The URL leads to a direct download of a PDF.

USDA NRCS. 2014. Cross Wind Trap Strips. Conservation Practice Standard Overview 589C. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263486.pdf.

This conservation practice overview from the USDA NRCS defines cross wind trap strips and briefly provides information about the conservation practice. It also lists commonly associated conservation practices. The URL leads to a direct download of a PDF.

Emergency Tillage



Emergency Tillage. Photo courtesy of the ARS.

Presley, D., E. Brokesh, P. Tomlinson, and J. Tatarko. 2013. Emergency Wind Erosion Control. MF2206. 4. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.k-state.edu/Item.aspx?catId=364&pubId=763.

This extension bulletin from Kansas State University provides a broad overview of emergency wind erosion control. It includes five tips for effective emergency tillage and information related to emergency tillage using mulching, emergency tillage in sandy soils, spacing of tillage operations, and more.

USDA NRCS. 2014a. Surface Roughening. Conservation Practice Standard 609. 2. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263510.pdf.

This USDA NRCS conservation practice standard defines surface roughening as tillage operations that create random roughness on the soil surface. It describes conditions that allow wind erosion and describes how emergency tillage works as well as how to correctly implement surface roughening on a field. The URL leads to a direct download of a PDF.

USDA NRCS. 2014b. Surface Roughening. Conservation Practice Standard Overview 609. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263487.pdf.

This USDA NRCS conservation practice standard overview concisely describes surface roughening. It includes a picture of the practice and a list of associated conservation practices, which include reduced till, cross wind ridges, cross wind trap strips, herbaceous barriers, and establishing windbreak/shelterbelt. The URL leads to a direct download of a PDF.

USDA NRCS. 2017a. Crosswind Ridges. Conservation Practice Standard 588. 2. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1335272&ext=pdf.

This USDA NRCS conservation practice standard defines crosswind ridges as a surface roughening practice in which ridges are formed from normal tillage, planting, and other operations in which ridges are aligned perpendicular to the prevailing wind. It provides general criteria for the practice, and what should considered when implementing the practice. The URL leads to a direct download of a PDF.

USDA NRCS. 2017b. Crosswind Ridges. Conservation Practice Standard Overview 588. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_025659&ext=pdf.

This USDA NRCS conservation practice standard overview provides a concise description of crosswind ridges with a picture and a list of associated conservation practices like conservation crop rotations, cover crop, and residue and tillage management. The URL leads to a direct download of a PDF.

Grassed Waterway



Grassed waterways carry runoff from crop fields preventing erosion. Photograph by Lynn Betts, courtesy of the USDA NRCS.

Ampim, P. A. Y., and F. Jaber. 10/11. Improving Water Quality with Grassed Waterways. 6. College Station, TX: Texas A&M AgriLife Extension Service. https://cdn-ext.agnet.tamu.edu/wp-content/uploads/2019/03/EL-5532_-Improving-Water-Quality-with-

Grassed-Waterways.pdf.

This extension bulletin from Texas A&M University provides a brief overview of grassed waterways with a general description and information for planning, designing, and maintaining grassed waterways. The URL leads to a direct download of a PDF.

McVay, K. A., G. M. Powell, and R. Lamond. 2004. Maintaining Grassed Waterways. 4. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=226&pubId=550.

This extension bulletin from Kansas State University outlines how to maintain already installed grassed waterways in the landscape. It begins with a general description of grassed waterways and details variations in design, selecting grasses, fertilizing and liming, inspections and maintenance, and managing for forage production and habitat.

USDA NRCS. 2007. Chapter 7 Grassed Waterways. In Engineering Field Handbook, 166. Washington, D.C.: USDA NRCS. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17766.wba.

This chapter from the USDA NRCS Engineering Field Handbook provides extensive technical details on the standard design and engineering considerations for grassed waterways. The chapter includes information on assessing the suitability of a site for grassed waterways, planning and design considerations, the design process, sizing channels, layout and construction, and maintaining grassed waterways. The URL leads to a direct download of a PDF.

USDA NRCS. 2014. Grassed Waterway. Conservation Practice Standard 550. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026051.pdf.

This practice standard defines grassed waterways as broad, shallow channels established with suitable vegetation to move surface water at non-erosive velocities to a stable outlet. It identifies criteria necessary for constructing and maintaining a grassed waterway and describes what else to take into account when installing a grassed waterway. The URL leads to a direct download of a PDF.

USDA NRCS. 2014. Grassed Waterway. Conservation Practice Standard Overview 550. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263483.pdf.

This conservation practice overview provides a brief description of grassed waterways. General information about the practice is provided, along with a list of commonly associated conservation practices. The URL leads to a direct download of a PDF.

Residue Management and Tillage Practices



Ridge-till soybeans emerge from warmed ground in the row surrounded by corn residue from the past year. Photograph by Gene Alexander, courtesy of the USDA NRCS.

Al-Kaisi, M., M. Hanna, and M. Duffy. 2009. Considerations in Selecting No-Till — Resource Conservation Practices. 6. Ames, Iowa: Iowa State University. https://store.extension.iastate.edu/product/Considerations-in-Selecting-No-Till-Resource-Conservation-Practices.

This extension publication provides insights into what should influence selecting no-till as an agricultural management practice. This bulletin highlights the effect of implementing a no-till system on crop yields, as well as notable management considerations like weed control, residue management, and equipment requirements. The authors suggest that, in most cases, converting from conventional tillage to no-till can be achieved without negatively affecting economic returns.



Closeup of no-till farming, the process of planting a crop without tilling the soil. Photograph by Lynn Betts, courtesy of the USDA NRCS.

Buchholz, D. D., E. Palm, G. Thomas, and D. L. Pfost. 1993, October. No-Till Planting Systems. https://extension2.missouri.edu/g4080.

This extension bulletin and webpage outline the advantages and disadvantages of a no-till system, highlighting other management decisions like field selection, fertility, crop residue, machinery, and pest control. Selecting machinery and managing pests is reviewed; these are areas typically require the most adjustment in implementing no-till.

DeJong-Hughes, J., and A. Daigh. 2018. Reducing Tillage Intensity. https://extension.umn.edu/soil-management-and-health/reducing-tillage-intensity.

This extension website outlines the benefits of reducing tillage and addresses some of the most common challenges (weed persistence, cost, and social perceptions). It describes different tillage methods and introduces some joint research conducted by the University of Minnesota and North Dakota State University. The research presented describes how tillage affects soil temperature, residue cover, and soil moisture. The results of two other research projects are show reduced tillage (strip-till in the examples) reduces the amount of soil organic carbon lost. This publication introduces important soil concepts for tillage and presents research results relevant to producers.

Idowu, J., S. Angadi, M. Darapuneni, and R. Ghimire. 2017. Reducing Tillage in Arid and Semi-Arid Cropping Systems: A Case Overview. Las Cruces: New Mexico State University. https://aces.nmsu.edu/pubs/_a/A152/welcome.html.

This extension bulletin describes the potential benefits of reduced tillage in the semi-arid and arid regions of New Mexico. The bulletin briefly defines tillage operations and the benefits of reducing tillage: controlling erosion, conserving soil

moisture, and accumulating soil organic matter. The bulletin is an overview of how tillage affects semi-arid and arid environments and the mechanisms by which reducing tillage improves soil conditions and reduces erosion. This resource offers a short summary of some agronomic and economic research specific to environments like the southwestern US.



Conservation tillage in central Iowa. Leaving crop residues on the soil surface at harvest reduces soil erosion significantly. Photograph by Tim McCabe, courtesy of the USDA NRCS.

USDA NRCS. 2012. Residue and Tillage Management, No Till. Conservation Practice Standard Overview 329. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1254958.pdf.

This USDA NRCS conservation practice standard overview defines residue and tillage management: no-till/strip till/direct seed as practices that target the amount, orientation, and distribution of crop residue that remains on the soil surface year round. It includes an image of soybean seedlings growing through the residue of the previous crop. The overview also includes a brief summary of general information about when the practice is used, benefits of no-till management, and operation and maintenance considerations. A list of common associated practices is included covering conservation crop rotation, nutrient management, pest management, and irrigation water management. The URL leads to a direct download of a PDF.

USDA NRCS. 2012. Residue Management, Mulch Till. Conservation Practice Standard Overview 345. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1254982.pdf.

This conservation practice standard overview defines reduced tillage, or “mulch till” as a practice that manages distribution, orientation, and amount of residue on the soil surface all year with limited soil disturbance to produce crops. The publication provides brief information about the practice, describes the benefits of the practice, and lists commonly associated conservation practices. Associated practices include conservation crop rotation, nutrient management, pest management, and irrigation water management. The URL leads to a direct download of a PDF.

USDA NRCS. 2012. Residue Management, Reduced Till. Conservation Practice Standard 345. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1251402.pdf.

This USDA NRCS conservation practice standard defines residue and tillage management in reduced till. Reduced till is defined as managing the crop or other plant residue on the soil surface year-round while also limiting soil disturbance from crop production. The standard describes the purpose of reduced tillage and sets minimum criteria that must be met when implementing reduced till as a conservation practice. The standard also outlines general considerations, details for plans and specifications, and considerations for operation and maintenance. The URL leads to a direct download of a PDF.

USDA NRCS. 2016. Residue and Tillage Management, No Till. Conservation Practice Standard 329. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1249901.pdf.

This conservation practice standard defines no till as limiting soil disturbance while managing the distribution, orientation, and amount of plant residue on the soil surface year-round. It describes why and where no till management is

implemented. The standard describes the purpose of no till and provides the minimum criteria for implementing the conservation practice. The standard also describes general considerations for the practice, soil health and organic matter content, increasing plant-available moisture, wildlife food and cover, plans and specifications, and operation and maintenance. The URL leads to a direct download of a PDF.

Stripcropping



Alternating strips of alfalfa with corn on the contour protects this crop field in northeast Iowa from soil erosion. Photograph by Tim McCabe, courtesy of the USDA NRCS.

USDA NRCS. 2017b. Stripcropping. Conservation Practice Standard 585. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1335270&ext=pdf.

This conservation practice standard from the USDA NRCS defines stripcropping as growing rotations of erosion-susceptible and erosion-resistant crops or fallow systematically in strips across a field. This reduces rill and sheet erosion from water and wind erosion, as well as reduces movement of nutrients, sediment, and pesticides. The standard lists criteria for implementing the practice on farmland, general considerations, information related to plans and specifications, and operation and maintenance information. The URL leads to a direct download of a PDF.

USDA NRCS. 2017a. Stripcropping. Conservation Practice Standard Overview 585. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_026169&ext=pdf.

This NRCS conservation practice overview defines stripcropping as systematically growing crops in strips in a field to reduce soil erosion. The overview includes a brief summary of information about the practice and a list of commonly associated conservation practices, including conservation crop rotation, cover crop, residue and tillage management, nutrient management, and integrated pest management. The URL leads to a direct download of a PDF.



Terraces and no-till farming work to control erosion on a farm in Montgomery County, Iowa. Photograph by Tim McCabe, courtesy of the USDA NRCS.

USDA NRCS. 1990. Farming and Maintaining Terraces. 20. Washington, D.C.: USDA. https://nrcspad.sc.egov.usda.gov/DistributionCenter/product.aspx?ProductID=131.

This booklet from the NRCS uses pictures, figures, and text to show terraces as an effective conservation practice. It covers the different types of terraces (broadbase, steep-backslope, and narrow-base), related conservation practices, information for farming terraced land, and maintenance of terraces.

USDA NRCS. 2014a. Terraces. Conservation Practice Standard 600. 2. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263187.pdf.

This conservation practice standard from the USDA NRCS defines terraces as combinations of a ridge and channel, or earth embankments, constructed across a field slope. The purpose is to reduce erosion, trap sediment, and retain runoff for soil moisture conservation. The standard outlines conditions where the practice applies, criteria, considerations, information for plans and specifications, and information for operation and maintenance. The URL leads to a direct download of a PDF.

USDA NRCS. 2014b. Terraces. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263415.pdf.

This conservation practice overview defines terraces as combinations of a ridge and channel, or earth embankments, constructed across a field slope, and general information about the conservation practice. The overview also lists commonly associated conservation practices, including grassed waterways, underground outlets, and subsurface drains. The URL leads to a direct download of a PDF.

USDA NRCS. 2017. Chapter 8 Terraces. In Engineering Field Handbook, 99. Washington, D.C.: USDA NRCS. https://directives.sc.egov.usda.gov/31181.wba.

This chapter from the USDA NRCS Engineering Field Handbook provides in-depth details on the design, construction, use, and maintenance of terraces. In addition, planning considerations are provided, along with definitions of nomenclature. Detailed information is provided for the various types of terrace cross sections, terrace alignment and spacing, and terrace channels and outlets. The three primary types of terraces described are broadbase, steep-backslope, and narrow-base terraces. Useful photos, figures, and engineering schematics are provided throughout the chapter. The URL leads to a direct download of a PDF.



Field windbreak in northwest Iowa. Photograph by Lynn Betts, courtesy of the USDA NRCS.

USDA NRCS. 2010. Windbreak/Shelterbelt Renovation. Conservation Practice Standard 650. 2. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026107.pdf.

This USDA NRCS conservation practice standard defines renovation of windbreaks and shelterbelts as removing, replacing, or releasing trees and shrubs from an existing windbreak or shelterbelt, or adding or removing rows from a windbreak or shelterbelt, or removing branches from trees and shrubs. For existing windbreaks, this may entail replacing an existing windbreak, removing selected trees, adding rows, or removing selected branches of trees or shrubs. The standard describes the purpose and provides criteria for applying windbreaks and shelterbelts. Considerations for implementing the practices are also described. The URL leads to a direct download of a PDF.

USDA NRCS. 2011. Windbreak/Shelterbelt Establishment. Conservation Practice Standard 380. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046943.pdf.

This conservation practice standard from the USDA NRCS defines windbreaks, also known as shelterbelts. The standard also discusses why the conservation practice is used and provides guidelines. Windbreaks are defined as single or several rows of trees or shrubs in linear configurations perpendicular to the predominant wind direction. Benefits of windbreaks include reducing soil wind erosion, protecting plants from potential wind damage, improving the soil microenvironment for increased plant yield, managing snowfall dispersion, and improving irrigation efficiency. The URL leads to a direct download of a PDF.

USDA NRCS. 2012. Windbreak/Shelterbelt Establishment (380) or Renovation (650). Conservation Practice Standard Overview 380. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255014.pdf.

This conservation standard practice overview from the USDA NRCS defines windbreak/shelterbelt as planting one or several rows of trees or shrubs in linear configurations aligned perpendicular to the predominant wind direction. The overview includes information about the conservation practice and a list of commonly associated conservation practices, which includes conservation crop rotation, cover crop, residue management, tree/shrub site preparation, tree/shrub establishment, tree/shrub pruning, and upland wildlife habitat management. The URL leads to a direct download of a PDF.

Wright, B., and R. Straight. 2019. Chapter 6 Windbreaks. In Training Manual for Applied Agroforestry Practices, 2018 Edition, 92–113. Columbia, MO: University of Missouri Center for Agroforestry. http://centerforagroforestry.org/pubs/training/index.php.

This book chapter the University of Missouri Center for Agroforestry presents training on windbreaks for foresters, farmers, and conservationists. It is thorough and covers windbreak function, benefits, design, site preparation, planting, and maintenance. It also includes an anecdote describing the successful experience of a Nebraska farmer using windbreaks in his operation. Another section outlines the economics of windbreaks. The chapter includes a list of additional resources and has a review exercise at the end to assess reader understanding, complete with answers to the exercises.

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2.2: Conservation Practices for Shorelines, Streams, and Wetlands

Abbreviations

EPA – US Environmental Protection Agency
PDF – Portable Document Format
NC – North Carolina
NRCS – Natural Resources Conservation Service
SWCS – Soil and Water Conservation Society
URL – Uniform Resource Locator
US – United States
USACE – US Army Corps of Engineers
USDA – US Department of Agriculture
USFWS – US Fish and Wildlife Service

Streambank, Shoreline, and Coastal Protection



The AGRON 635 – Soil and Water Conservation Class at Kansas State University listens to water quality forester, Andy Klein during a tour of a riparian buffer strip on the Big Blue River in Kansas.

Broome, S. 2015. Restoration and Management of Coastal Dune Vegetation. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/restoration-and-management-of-coastal-dune-vegetation.

> Coastal dunes perform many functions, protecting low-lying areas, acting as barriers against storm surge and waves, and providing habitat to migratory birds and other animals. This extension bulletin from North Carolina State University describes these functions of beach-dune systems. It focuses primarily on beach dune restoration, including grasses, fertilization, construction, and protection.

National Research Council. 2007. Chapter 3 Methods for Addressing Erosion. In Mitigating Shore Erosion Along Sheltered Coasts, 44–77. Washington, D.C.: National Academies Press. https://www.nap.edu/read/11764/chapter/5.

> This chapter from *Mitigating Shore Erosion AlongSheltered Coasts* focuses on strategies for limiting erosion on shorelines. The strategies can be grouped into soft and hard methods of conservation. Soft methods described in this chapter include managing land use, vegetation, marshland, seagrass, and vegetated dunes. Hardened structures described include bulkheads, seawalls, revetments, breakwalls, and sills. Strategies to trap or add sand are also discussed in detail, including beach nourishment, groins, and breakwaters, among others. The chapter then provides design elements and criteria for implementing conservation practices on shores and coasts.

USDA NRCS. 1996. Chapter 16 Streambank and Shoreline Protection. *In* Engineering Field Handbook, 143. Washington, D.C.: USDA NRCS. https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21429

> Chapter 16 of the *Engineering Field Handbook* from the USDA NRCS provides technical details for streambank and shoreline protection practices. This chapter should help engineers determine appropriate measures to minimize streambank and shoreline erosion.

USDA NRCS. 2010. Streambank and Shoreline Protection. Conservation Practice Standard 580. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046931.pdf.

This conservation practice standard overview defines streambank and shoreline protection as applying structural or vegetative measures to protect and stabilize banks of streams, lakes, estuaries, or excavated channels. This standard includes the purpose of the practice, conditions where it applies, criteria, considerations, plans and specifications, and operation and maintenance. The URL leads to a direct download of a PDF.

USDA NRCS. 2012. Streambank and Shoreline Protection. Conservation Practice Standard Overview 580. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255166.pdf.

This document defines streambank and shoreline protection as applying structural or vegetative measures that protect and stabilize banks of streams, lakes, estuaries, or excavated channels. The USDA NRCS provides a general overview of the practice and closes by listing conservation practices commonly associated with streambank and shoreline protection. Those practices include riparian forest buffers, riparian herbaceous buffers, fences, channel bed stabilization, and open channels.

Stream Conservation

Allen, H. H., and J. R. Leech. 1997. Bioengineering for Streambank Erosion Control. Report 1 – Guidelines. 105. Vicksburg, MS: USACE, Waterways Experiment Station. http://www.dtic.mil/docs/citations/ADA326294.

This report from the USACE outlines bioengineering of streams to prevent streambank erosion. Bioengineering streams requires using living organisms like trees and other plantings along streams to protect the stream from erosion instead of using rip rap and other expensive, hard engineering practices. The report synthesizes bioengineering applications and provides preliminary planning and design guidelines for eroded streambanks. This document can be used as a guide to bioengineering projects but should not be used as a cookbook. The guidelines include the scope of the practices and details on planning, hard structures, and bioengineering, bioengineering by zones, bioengineering treatments, and velocities. It also outlines plant acquisition, handling, and timing of planting, as well as information about monitoring, aftercare, and costs.

EPA. 2015, September 15. Hydromodification and Habitat Alteration: National Management Measures. https://www.epa.gov/nps/hydromodification-and-habitat-alteration-national-management-measures.

The EPA developed this document to guide implementation of hydromodification projects to reduce surface and groundwater pollution from nonpoint sources.

EPA Office of Water, O. 2016, September 14. Stream Corridor Restoration Tools. https://www.epa.gov/watershedacademy/stream-corridor-restoration-tools.

This web page provides an index to the eleven sections of the Watershed Technology Electronic Catalog. The Watershed Technology Electronic Catalog contains media and text on 150 watershed management practices. This resource gives watershed managers and restoration practitioners a starting point for restoration design projects. These design products should be modified to fit individual projects by skilled professionals after in depth site analysis and planning.

Iowa Department of Natural Resources, and USDA NRCS. 2006. How to Control Streambank Erosion. http://www.iowadnr.gov/portals/idnr/uploads/water/stormwater/streambankmanual.pdf

This manual from the Iowa Department of Natural Resources, published in cooperation with the USDA NRCS, addresses controlling streambank erosion. It describes in detail several control methods that are most applicable in Iowa and other midwestern states. The manual primarily focuses on bioengineering methods and is not a technical manual but a planning aid for streambank protection projects. The URL leads a direct download of a PDF.

Channel Bed Stabilization



FT Ranch Boys fish on Trinchera Creek in Colorado. Photograph by Gary Kramer, courtesy of the USDA NRCS.

USDA NRCS. 2015. Channel Bed Stabilization. Conservation Practice Standard 584. 3. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1255169&ext=pdf.

> In this conservation practice standard, the USDA NRCS describes how to stabilize stream channel beds. The standard includes conditions where the practice could be applied and what should be considered when attempting streambed stabilization. It also includes details for plans and specifications and operations and maintenance. The URL leads to a direct download of a PDF.

USDA NRCS. 2015. Channel Bed Stabilization. Conservation Practice Standard Overview 584. Practice Introduction. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_026241&ext=pdf.

> This overview from the USDA NRCS provides a brief summary of channel bed stabilization, describing how and under what circumstances channel beds should be altered for stabilization, as well including a few parameters and precautions. It has a list of conservation practices commonly associated with channel bed stabilization, including streambank and shoreline protection, clearing and snagging, and open channel. The URL leads to a direct download of a PDF.

Filter Strips



A grass filter strip along a stream in Carroll County, Iowa. Photograph by Gary Kramer, courtesy of the USDA NRCS.

Grimser, M. E., A. T. O'Geen, and D. Lewis. 2006. Vegetative Filter Strips for Nonpoint Source Pollution Control in Agriculture. 7. Oakland, CA: University of California Division of Agriculture and Natural Resources. https://anrcatalog.ucanr.edu/Details.aspx?itemNo=8195#FullDescription.

This extension bulletin from the University of California provides a general overview of vegetative filter strips. Design considerations are described, and examples of pollutant removal efficiency are provided in table format. An example design for an irrigated farming operation are provided. This bulletin caters to horticultural crop producers, farm managers, and practitioners.

Smyth, A., R. Muñoz-Carpena, and Y. Li. 2015. Vegetative Filter Strips–A Best Management Practice for Controlling Nonpoint Source Pollution. Extension Bulletin SL432. 5. Gainesville, FL: University of Florida Institute of Food and Agriculture Sciences Extension. https://edis.ifas.ufl.edu/ss646.

This extension publication from the University of Florida gives a concise description of vegetative filter strips and provides an overview of the primary functions, design factors, and effectiveness for removing emerging pollutants. A number of figures help convey the main points presented in the bulletin.

USDA NRCS. 2016b. Filter Strips. Conservation Practice Standard 393. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1241319.pdf.

This conservation standard practice defines filter strips as an area of vegetation established for removing organic material, sediment, and other pollutants from wastewater and runoff. The standard includes information on the purpose of filter strips, conditions where the practice applies, criteria, considerations, plans, and specifications, as well as information on operation and maintenance. The URL leads to a direct download of a PDF.

USDA NRCS. 2016a. Filter Strips. Conservation Practice Standard Overview 393. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_025826&ext=pdf.

This conservation practice standard gives an overview in which the USDA NRCS defines filter strips as an area of vegetation established for removing organic material, sediment, and other pollutants from wastewater and runoff. It includes a brief overview of filter strips and offers a list of associated conservation practices. Those include nutrient management, integrated pest management, waste recycling, and residue and tillage management. The URL leads to a direct download of a PDF.

Riparian Forest Buffer



Rows of trees and shrubs, as well as a native grass strip, combine in a riparian buffer to protect Bear Creek in Story County, Iowa. The buffer is a nationally designated demonstration area for riparian buffers. Photograph by Lynn Betts, courtesy of the USDA NRCS.

Kansas State University Horticulture and Natural Resources. 2018, May 25. Riparian Buffers. https://hnr.k-state.edu/extension/publications/riparian-buffers.html.

This website includes a table with hyperlinks to eight extension bulletins from Kansas State University on streamside forestry and riparian forest buffers. Topics include riparian forest buffers, streambank protection, timber management, planting, and more.

Klapproth, J. C., and J. E. Johnson. 2009. Understanding the Science Behind Riparian Forest Buffers: An Overview. 4. Blacksburg, VA: Virginia Polytechnic Institute and State University. https://www.pubs.ext.vt.edu/420/420-150/420-150.html.

This extension bulletin from Virginia Polytechnic Institute and State University provides a concise overview of riparian forest buffers as an ecosystem, as well as information on the effects of these buffers on water quality, living resources, and social and community benefits. Virginia's riparian buffer implementation plan is also summarized.

USDA NRCS. 2010. Riparian Forest Buffer. Conservation Practice Standard 391. 3. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026098.pdf.

This USDA NRCS conservation practice standard defines riparian forest buffers as areas with predominantly trees or shrubs adjacent to and up-slope from streams and other water bodies. The purpose of these buffers is to provide shade for water bodies to keep temperatures low, improve habitat, reduce sediment and other pollutants, and more. The standard describes where the practice applies, criteria for the practice, general considerations, plans and specifications, and operation and maintenance. The URL leads to a direct download of a PDF.

USDA NRCS. 2012. Riparian Forest Buffer. Conservation Practice Standard Overview 391. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255022.pdf.

This USDA NRCS conservation standard overview provides a definition of riparian forest buffer, a brief description of the practice, and a list of commonly associated conservation practices. Those practices include riparian herbaceous cover, stream habitat improvement and management, streambank and shoreline protection, and tree/shrub establishment. The URL leads to a direct download of a PDF.

Virginia Department of Forestry. 2014, November 6. Riparian Forest Buffers. http://www.dof.virginia.gov/manage/riparian/index.htm.

This website from the Virginia Department of Forestry contains general information on riparian forest buffers, primarily for citizens of the commonwealth of Virginia. The site features many links to additional resources on riparian forest buffers, including links to each extension bulletin from Virginia Polytechnic Institute and State University in a series called "Understanding the Science Behind Riparian Forest Buffers."

Saturated Buffers



Installation of a saturated buffer in Story County, Iowa. Photograph by Lynn Betts, courtesy of the USDA NRCS and SWCS.

Jaynes, D., B. Reinhart, C. Hay, J. Kjaersgaard, K. Nelson, N. Utt, S. Jacquemin, and T. Isenhart. 2018. Questions and Answers About Saturated Buffers. Extension Publication ABE-160. 8. West Lafayette, IN: Purdue University. https://edustore.purdue.edu/.

This extension publication from Purdue University, Iowa State University, and others is in question-and-answer format, providing a concise, yet thorough, overview of saturated buffers. It begins with a definition of saturated buffers: an edge-of-field practice designed to remove nitrate from drainage water before it enters nearby surface waters. Examples of installations with descriptions and pictures are provided for different scenarios. Other information includes benefits to water quality, effect on crop yield; length of saturated buffers; management and vegetation considerations; costs and regulations; and appropriate sites.

SWCS. 2019. Saturated Buffer Facts. https://www.swcs.org/resources/conservation-media-library/saturated-buffer-facts.

This web page from the SWCS Conservation Media Library provides an overview of saturated buffers, a conservation practiced designed to improve water quality from agricultural drainage water. The web page includes a description of the conservation practice, a summary of benefits of the practice, and lists some economic considerations. It also includes a list of other credible sources of information on saturated buffers.

SWCS Events. 2018. Saturated Buffers: A Nutrient Removal Option for Farmers. Ankeny, IA: SWCS. https://vimeo.com/291573566.

This brief video from the SWCS features experts on saturated buffers: Dan Jaynes, a researcher from the ARS; Willie Ubben, a tiling contractor; and Justin Hanson, a corn and soybean farmer from Iowa. Saturated buffer installation is generally described, images are included, and the effectiveness of saturated buffers for removing nitrate from drainage water are discussed.

USDA NRCS. 2016a. Saturated Buffer. Conservation Practice Standard 604. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1051806&ext=pdf.

This conservation practice standard from the USDA NRCS defines saturated buffers as a subsurface drainage tile line used to divert and spread drainage water discharge along a vegetated area to increase soil saturation. The standard outlines where this practice is applicable, criteria for determining appropriate locations and soils, general considerations, plans and specifications, and operation and maintenance concerns. The URL leads to a direct download of a PDF.

USDA NRCS. 2016b. Saturated Buffer. Conservation Practice Standard Overview 604. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1053609&ext=pdf.

This conservation practice overview from the USDA NRCS defines saturated buffers, provides a brief overview of the practice, and lists commonly associated practices. Those practices include nutrient management and drainage management. The URL leads to a direct download of a PDF.

Stream Crossings



Cattle pass over a gravel-lined stream crossing. Photograph by Tim McCabe, courtesy of the USDA NRCS.

Higgins, S., C. Agouridis, and S. Wightman. 2011. Stream Crossings for Cattle. 7. Lexington, KY: Kentucky Cooperative Extension. http://www.ca.uky.edu/agc/pubs/aen/aen101/aen101.pdf.

This extension bulletin from Kentucky Cooperative Extension provides an overview of stream crossings for cattle. This bulletin provides livestock producers with instructions for installing stream crossings for livestock and vehicles. Many figures are provided, along with reference tables and examples.

USDA NRCS. 2017. Stream Crossing. Conservation Practice Standard 578. 6. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1335269&ext=pdf.

This conservation practice standard from the USDA NRCS defines stream crossings as stabilized areas or structures across streams that facilitate travel for livestock, people, equipment, or vehicles. The practice improves water quality by reducing sediment, nutrient, or organic loading to streams, as well as reducing streambank and streambed erosion. The conditions suitable for the practice are described, along with criteria, general considerations, information for developing plans and specifications, and operation and maintenance considerations.

USDA NRCS. 2017. Stream Crossing. Conservation Practice Standard Overview 578. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1364066&ext=pdf.

This conservation standard practice overview from the USDA NRCS defines stream crossings as a conservation practice. It also provides a brief overview of the conservation practice and lists commonly associated practices.

Stream Fencing



Fencing cattle away from a stream is an important measure for water quality that these northeast Iowa farmers are adopting. Photograph by Tim McCabe, courtesy of the USDA NRCS.

Goard, D. 2006. Fencing. 2. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.kansasforests.org/streamside_forestry/streamside_docs/Fencing.pdf.

In this Kansas State University extension bulletin, Goard describes why fencing is used to exclude livestock and cattle from riparian buffer strips. outlines the problems with unrestricted grazing in riparian areas, and explains how excluding grazing from these areas can be beneficial. Goard goes on to summarize how to implement fencing along riparian corridors.



Canadian geese rest in a wetland on the eastern shore of Maryland. Photograph by Tim McCabe, courtesy of the USDA NRCS.

Dahl, T. E., and G. J. Allord. 1996. History of wetlands in the conterminous United States. In National Water Summary on Wetland Resources, ed. J. D. Fretwell, J. S. Williams, and P. J. Redman. USGS Water-Supply. https://www.fws.gov/wetlands/Documents/History-of-Wetlands-in-the-Conterminous-United-States.pdf.

Dah and Allord summarize the history of wetlands in the US dating back to the colonial period. The periods include the colonial period (1600s to 1800s); westward expansion (1800-1860); agriculture moves west (1860-1900); technology changing (1900-1950); and changing priorities and values (1950-present). In all but the last period, wetland loss was widespread, and in some cases, incentivized by the government. For each period, Dahl and Allord describe how wetlands were destroyed and why they were destroyed. For the most recent period, Dahl and Allord describe how the values and ecological services provided by wetlands began to be recognized, resulting in greater perceived value by the public and state and federal legal protection of wetlands. The URL leads to a direct download of a PDF.

Sucik, M., and E. Marks. 2014. The Status and Recent Trends of Wetlands in the United States. 25. Ames, Iowa: US Department of Agriculture Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/.

This National Resources Inventory report on wetlands for 2010 summarizes changes to wetlands in the US. It includes a brief history of wetlands in the US, then summarizes trends in wetland area across different regions. The general trend is that wetland area has decreased over the history of the National Resources Inventory. Case studies from three different regions highlight pressures triggering wetland loss and efforts to prevent or reverse that loss. The report closes with a description of the National Resources Inventory.

US EPA Office of Water. 2019, May 20. Wetland Functions and Values. https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=262.

In this module, the EPA highlights the full scope of the beneficial attributes of wetlands. The module provides a discussion of how wetlands have become appreciated for their role in providing healthy ecosystems, as well as their benefits to our economy through commercial fishing and cleaner water. The module also highlights other services that wetlands provide: among them, sustainability, recreation, and research.

USDA NRCS. 2008a. Chapter 13 Wetland Restoration, Enhancement, or Creation. In Engineering Field Handbook, 150. Washington, D.C.: USDA NRCS. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17765.wba.

As stated in the purpose and scope of this chapter, wetland creation, restoration, or enhancement requires a multidisciplinary approach involving soil science, biology, geology, and engineering. Thus, this chapter is an expansion of the Engineering Field Handbook that encompasses the expanded scope of wetland management. This 150-page document includes information on hydrogeomorphic classification of wetlands and wetland processes and characteristics, as well as guidelines for planning, designing, constructing, and managing wetlands.

USDA NRCS. 2008b. Hydrogeomorphic Wetland Classification System: An Overview and Modification to Better Meet the Needs of the Natural Resources Conservation Service. 10. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_010784.pdf.

This technical note was issued in 2008 to guide USDA NRCS staff when assessing hydrogeomorphic (HGM) wetlands. It provides an overview of original HGM concepts and supplies additional structure to the classification system. HGM classification is used in assessing changes to wetlands from proposed projects, wetland improvements, among others. Since its inception in 1993, HGM classification has been solely based on the geographic setting of the wetland in question. However, vegetation and soil properties may more strongly influence wetland function than geography. The USDA NRCS acknowledged this idea in this technical note and subsequently encouraged NRCS staff to include modifiers to original HGM classes to more accurately describe wetland characteristics. The URL leads to a direct download of a PDF.

USDA NRCS. 2015. Chapter 19 Hydrology Tools for Wetland Identification and Analysis. In Engineering Field Handbook, 61. Washington, D.C.: USDA NRCS. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=37808.wba.

Jurisdictional wetlands require the presence of hydric soils, hydrophytic vegetation, and wetland hydrology. This chapter from the Engineering Field Handbook describes the available tools that use onsite and offsite data to document the presence of wetland hydrology beyond onsite wetland hydrology field indicators. Chapter contents include descriptions of data sources like weather, soils, and streams and how to use that data for hydrologic modeling.

USDA NRCS. 2017. Field Indicators of Hydric Soils in the United States: A Guide for Identifying and Delineating Hydric Soils. (L. M. Vasilas, G. W. Hurt, and J. F. Berkowitz, Eds.) Version 8.0. Washington, D.C.: USDA NRCS in cooperation with the National Technical Committee for Hydric Soils. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053171.pdf.

This technical guide for recognizing hydric soil indicators was developed by the National Technical Committee for Hydric Soils, which includes representatives from USDA NRCS, USFWS, USACE, EPA, academia, and others. It should help staff identify, delineate, and verify hydric soils in the field. It groups and describes indicators as they relate to all soils and then groups and describes indicators specific to soil textures. In addition to field indicators, this guide includes test indicators. The test indicators should not be used to delineate hydric soils but to encourage submission of potential indicator descriptions and supporting data. In this way, the list of approved indicators can be expanded. The URL leads to a direct download of a PDF.

Wetland Creation



A conservationist in Sunflower County, Mississippi discuss a landowner's plan to restore wetlands and grasslands among cotton fields to improve water quality and wildlife habitat.

Frentress, C., J. C. Cathey, C. D. Mason, T. Parks, R. Hirsch, and M. W. Wagner. 2007. Techniques for Wetland Construction and Management. 23. College Station, TX: Texas A&M University. http://wildlifehabitat.tamu.edu/Lessons/Wetland-Management/Readings/Wetland-Construction-and-Management.pdf.

The objective of this extension publication from Texas A&M is to provide land managers with information on restoring, creating, or enhancing wetlands. The first table summarizes wetland ecosystem services and the functions wetlands perform for that ecosystem. The introduction includes a description of wetland ecosystems, economic benefits from wetlands, and the intrinsic value of wetlands. The authors then present information on wetland construction and management and how wetlands can be managed under different scenarios. The URL leads to a direct download of a PDF.

USDA NRCS. 2010. Wetland Creation. Conservation Practice Standard 658. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025863.pdf.

This USDA NRCS conservation practice standard outlines the definition, purpose, conditions, criteria, and considerations of wetland creation. Wetland creation seeks to establish wetland hydrology, vegetation, and wildlife habitats on soils that can support wetland functions. This practice does not apply to areas used to treat water resource pollution, areas of wetland rehabilitation, or wildlife habitat management following wetland establishment. The local hydrology and soils must be suitable to maintain wetland conditions. Native vegetative species should be used to cultivate the wetland. In planning wetland creation, considerations should include how the the proposed wetland could affect the environment in the surrounding area. The URL leads to a direct download of a PDF.

USDA NRCS. 2012. Wetland Creation. Conservation Practice Standard Overview 658 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255219.pdf.

This USDA NRCS conservation practice standard overview defines wetland creation as establishing a wetland on land that was previously not a wetland. In the practice information section, the purpose of wetland creation should be creating wetland functions and values. The overview closes with a list of associated conservation practices, including dikes, structures for water control, grade stabilization structures, pond sealing and lining, and use exclusion. The URL leads to a direct download of a PDF.

Wetland Enhancement

USDA NRCS. 2010. Wetland Enhancement. Conservation Practice Standard 659. 5. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026454.pdf.

This USDA NRCS conservation practice standard outlines the definition, goals, criteria, and considerations in enhancing wetlands. The goal of wetland enhancement is to augment specific wetland functions beyond what naturally occurring conditions allow, sometimes at the expense of other wetland functions, using soil, vegetation, hydrology, and wildlife habitats. This practice does not apply to the treatment of water pollution sources, rehabilitation of wetlands, restoration of a historic wetland, or wetland establishment. The URL leads to a direct download of a PDF.

USDA NRCS. 2012. Wetland Enhancement. Conservation Practice Standard Overview 659. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255220.pdf.

This USDA NRCS conservation practice standard overview defines wetland enhancement as modification of an existing wetland or reestablishment of a degraded wetland for the purposes of favoring specific wetland functions. It provides a brief description of where this practice applies and the purposes of this practice. It closes with a list of commonly associated conservation practices, including dikes, structures for water control, fencing, fish passages, and use exclusion. The URL leads to a direct download of a PDF.



A restored wetland in California. Photograph by Gary Kramer, courtesy of the USDA NRCS.

USDA NRCS. 2007. Noxious, Invasive, and Alien Plant Species: A Challenge in Wetland Restoration and Enhancement. Technical Note 190-72. 26. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/wetlands/restore/?cid=nrcs143_010912.

> The purpose of this technical note is to inform USDA NRCS staff of plant species that prevent successfully restoring and enhancing wetlands. It defines five categories of plants, listed in order of increasing threat: native, alien, weeds, invasive, and noxious. Alien, weeds, invasive, and noxious species displace native vegetation and thus interfere with wetland enhancement and restoration, reducing biodiversity, reducing wildlife habitat and food resources, and disrupting ecosystem processes. This technical note includes a list of common invasive and noxious plant species that impair wetland enhancement and restoration and describes their dispersal methods and control practices. Mitigating the spread of such species requires familiarity with potential threats in an area, anticipating sources of harmful plant species, developing monitoring protocols, and encouraging establishment of native species in disturbed areas.

USDA NRCS. 2008. Stream Water Surface Profile Modification for Wetland Restoration. Technical Note 1. 25. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1243051&ext=pdf.

> This technical note from the USDA NRCS applies to riverine wetlands in which the wetland hydrology has changed due to incision of the stream channel and is used for developing strategies for restoring or enhancing the connectivity between the floodplain and the stream. The technical note begins with background information for classifying or describing wetlands and stream channels, including hydrogeomorphic wetland classification, landscape position, hydrology, and stream channel classification. Then, wetland restoration or enhancement and hydrology restoration strategies are described in detail, including design conditions for various scenarios, as well as guidelines for modeling hydrology for such conditions.

USDA NRCS. 2010. Wetland Restoration. Conservation Practice Standard 657. 5. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026340.pdf.

> This USDA NRCS conservation practice standard defines wetland restoration as the return of a wetland and its functions to an approximation of its conditions before disturbance. Restoration restores site conditions favorable for hydric soil properties, wetland hydrology, native hydrophytic vegetation, and native wildlife habitats. Wetland restoration does not include treating water resource pollution areas, wetland rehabilitation where enhancements have been made to certain functions, wetland creation, or wildlife habitat management. The practice standard provides the criteria, recommendations, and considerations for restoring hydric soil properties, wetland hydrology, hydrophytic vegetation, and wildlife habitats. It also recommends maintenance following restoration for such things as pests, sediment load, and invasive species.

USDA NRCS. 2011. Scenarios for Wetland Restoration. Technical Note 4. 33. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1243054&ext=pdf.

This USDA NRCS technical note provides general principles for wetland restoration as described in Conservation Practice Standard 657. These principles are presented in the context of nine different scenarios based on hydrogeomorphic wetland classification, hydrology, and topography.

USDA NRCS. 2012. Wetland Restoration. Conservation Practice Standard Overview 657. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255218.pdf.

This conservation practice standard overview defines wetland restoration as returning a wetland and its functions to an approximation of its conditions before disturbance. The goals of wetland restoration and considerations for the practice are briefly described. The overview concludes with a list of associated conservation practices, including dikes, structures for water control, habitat management, riparian herbaceous cover, and riparian forest buffer.

Wetland Wildlife Habitat Management



Red-eared turtles in a wetland. Photograph by Lynn Betts, courtesy of the USDA NRCS.

USDA NRCS. 2012a. Wetland Wildlife Habitat Management. Conservation Practice Standard 644. 2. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026455.pdf.

This USDA NRCS conservation practice standard defines wetland wildlife habitat management as retaining, managing, or developing wetland habitat for wetland wildlife. The standard further describes the purpose as to improve, develop, or maintain wetland habitat for waterfowl, shorebirds, fur-bearers, or other fauna and flora associated with wetlands. Conditions where the conservation practice applies and criteria for the practice are described, followed by considerations, plans and specifications, and operation and maintenance of the conservation practice. The URL leads to a direct download of a PDF.

USDA NRCS. 2012b. Wetland Wildlife Habitat Management. Conservation Practice Standard Overview 644. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255211.pdf.

This USDA NRCS conservation practice standard overview defines wetland wildlife habitat management as retaining, managing, or developing wetland habitat for wetland wildlife. The standard further describes the purpose as to improve, develop, or maintain wetland habitat for waterfowl, shorebirds, fur-bearers, or other fauna and flora associated with wetlands. Conditions where the conservation practice applies and other considerations for implementing the practice are briefly described. It concludes with a list of associated conservation practices, including wetland restoration, wetland enhancement, restoration and management of rare and declining habitats, shallow development and management, and upland wildlife habitat management, among others. The URL leads to a direct download of a PDF.

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2.3: Conservation Practices for Forest, Range, and Wildlands

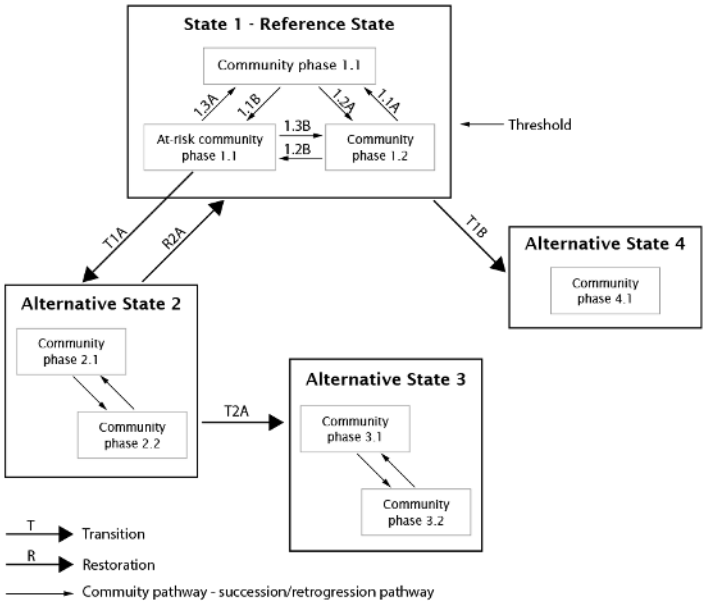
Abbreviations

BLM – Bureau of Land Management
BMP – Best Management Practice
DOI – US Department of the Interior
ESD – Ecological Site Description
ESI – Ecological Site Inventory
ESIS – Ecological Site Information System
FSGD – Forage Suitability Group Designation
PDF – Portable Document Format
NESH – National Ecological Site Handbook
NRCS – Natural Resources Conservation Service
TVA – Tennessee Valley Authority
US – United States
USDA – US Department of Agriculture
USFWS – US Fish and Wildlife Service
USFS – USDA Forest Service
URL – Universal Resource Locator

Ecological Site Descriptions

Caudle, D., H. Sanchez, J. DiBenedetto, C. Talbot, and M. Karl. 2013. The Interagency Ecological Site Handbook for Rangelands. 110. Washington, DC: The USDA NRCS, USFS, and DOE BLM. http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=33943.wba.

> The Interagency Ecological Site Handbook for Rangelands was developed by the BLM, USFS, and USDA NRCS to standardize how to describe and identify rangeland ecological sites to support inventory and how to monitor, evaluate, and manage rangelands in the US. The handbook is extensive, 112 pages in total. It is the preeminent information source for ecological site development. The handbook outlines ecological site classification concepts; classification, differentiation, and descriptions of ecological sites; delineation and mapping of ecological sites; and content of ecological site descriptions.



An example state and transition model. Figure adapted from Caudle et al. (2013).

The Jornada Rangeland Research Programs. 2019. Ecological Site Descriptions Development Resources. https://jornada.nmsu.edu/esd/development-resources.

This web page from the Jornada Rangeland Research Program includes links and downloads for resources useful for developing ecological site descriptions. It includes data forms, methods, and additional resources useful for developing ecological site descriptions.

USDA NRCS. 2019a. Ecological Sites. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1068392.

This web page provides a concise summary of ecological sites and related concepts. On this page, the USDA NRCS defines ecological sites as “the basic component of a land-type classification system that describes ecological potential and ecosystem dynamics of land areas.” The page includes further information on the background of ecological sites, forage suitability groups, soils and ecological sites, and state and transition models. Links to associated web pages are included throughout. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2019b. Ecological Site Information System. https://esis.sc.egov.usda.gov/.

This web page provides links to and short descriptions of the primary tools associated with ecological sites. These include the ESIS, the ESD database, FSGD, ESI, the Interagency Ecological Site Handbook for Rangelands, and the NESH.

Forestry Best Management Practices

Aber, J., N. Christensen, I. Fernandez, J. Franklin, L. Hidinger, M. Hunter, J. MacMahon, D. Mladenoff, J. Pastor, D. Perry, R. Slangen, and H. van Miegroet. 2000. Applying Ecological Principles to Management of the U.S. National Forests. Issues in Ecology (Number 6). https://www.esa.org/wp-content/uploads/2013/03/issue61.pdf.

Issues in Ecology reports the consensus of panels of scientific experts on environmental issues in language understandable by non-scientists. This issue presents the ecological principles that the authors think should be incorporated into management plans for US National Forests. The highlighted ecological concepts include soil and nutrient cycles, hydrology, biodiversity, landscape-level issues, global change, policy analysis assumptions, and what we know about forest ecosystems, natural stand dynamics, substituting silviculture for natural forest processes, and the ecological role of timber harvesting. The URL offers a direct download of a PDF of this resource.

US EPA Office of Water. 2019b, February 19. Forestry Best Management Practices in Watersheds. https://cfpub.epa.gov/watertrain/moduleFrame.cfm?module_id=34&parent_object_id=1517&object_id=1517.

Issues in Ecology reports the consensus of panels of scientific experts on environmental issues in language understandable by non-scientists. This issue presents the ecological principles that the authors think should be incorporated into management plans for US National Forests. The highlighted ecological concepts include soil and nutrient cycles, hydrology, biodiversity, landscape-level issues, global change, policy analysis assumptions, and what we know about forest ecosystems, natural stand dynamics, substituting silviculture for natural forest processes, and the ecological role of timber harvesting. The URL offers a direct download of a PDF of this resource.

USDA Forest Service. 2012. National Core BMP Technical Guide. Washington, D.C.: USDA Forest Service. https://www.fs.fed.us/naturalresources/watershed/bmp.shtml#TechGuideV2.

This publication provides general descriptions of best management practices. It is split into three parts: 1) introduction, 2) managing water quality on national forest system lands, and 3) national core BMPs. The third section is the most extensive, providing concise information about each practice. While the technical guide is extensive, the breadth of information for many BMPs makes it a useful reference for implementing conservation practices.



A firebreak in Queen Anne, Maryland. Photograph courtesy of the USDA NRCS.

USDA NRCS. 2010. Firebreak. Conservation Practice Standard 394. 2. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026527.pdf.

> In this conservation practice standard, the USDA NRCS defines a firebreak as a strip of bare or vegetated land that reduces the spread of wildfire or contains prescribed burns. The standard outlines criteria and considerations for implementing the practice, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2012. Firebreak. Conservation Practice Standard Overview 394. 1. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255035.pdf.

> This conservation practice standard overview provides a concise summary of firebreaks, including a definition, a general description of when they should be built, general considerations, and a list of associated conservation practices. The overview also includes an image of a firebreak containing a fire along a road used as a firebreak. Commonly associated practices are listed, including prescribed burning, forest trails and landings, forest stand improvement, and tree and shrub planting. The URL offers a direct download of a PDF of this resource.

Weir, J. R., T. G. Bidwell, R. Stevens, and J. Mustain. 2017. Firebreaks for Prescribed Burning. NREM-2890. Stillwater, OK: Oklahoma Cooperative Extension Service. http://factsheets.okstate.edu/documents/nrem-2890-firebreaks-for-prescribed-burning/.

> This extension bulletin several different types of firebreaks: natural firebreaks like bluffs, creeks, rivers, and lakes; existing firebreaks like cultivated fields and roads; and constructed firebreaks that are scraped, disked, or hand lines and mowed or watered lines. The bulletin also highlights other considerations such as firebreak width, brush piles, preventing erosion, and additional resources.



Park rangers and volunteers work on a National Public Lands Day trail project in Coconino National Forest. Photograph by Deborah Lee Soltesz, courtesy of the Coconino National Forest.

Bardon, R., L. Harkins, and M. Megalos. 2003. Recreational Forest Trails: Plan for Success. 12. Raleigh, NC: North Carolina Cooperative Extension Service. https://content.ces.ncsu.edu/recreational-forest-trails-plan-for-success.

This extension bulletin from North Carolina State University describes BMPs for recreational trails, including types of trails, studying the land, trail design and construction, trail specifications, designing for accessibility, and construction tips. It contains many useful hand-drawn diagrams and easy-to-understand tables and lists.

USDA NRCS. 2017. Forest Trails and Landings. Conservation Practice Standard 655. 2. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_026503&ext=pdf

In this conservation practice standard the USDA NRCS defines forest trails and landings as a temporary or infrequently used cleared area, path, or route. These trails are for travel by people or equipment or for periodic access for removing and collecting forest products. The standard covers general criteria for trails and landings, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2012. Forest Trails and Landings. Conservation Practice Standard Overview 655. 1. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255216.pdf.

In this conservation standard practice overview, the USDA NRCS defines forest trails and landings. Information about the practice is provided, including general criteria, specifications, and a list of commonly associated conservation practices. A picture of a forest soil is provided. Practices include access roads, critical area plantings, firebreaks, forest stand improvement, and more. The URL offers a direct download of a PDF of this resource.



A fuel break in California. Photograph by Gary Kramer, courtesy of the USDA NRCS.

Bennett, M., S. A. Fitzgerald, B. Parker, M. Main, A. Perleberg, C. C. Schnepf, and R. Mahoney. 2010. Chapter 4: Firebreaks and Shaded Fuelbreaks. In Reducing Fire Risk on Your Forest Property, 13–15. Corvallis, Oregon: Oregon State University, University of Idaho, Washington State University. https://catalog.extension.oregonstate.edu/pnw618.

This chapter from the Reducing Fire Risk on Your Property outlines general guidelines for firebreaks and shaded fuel breaks. The three-page chapter highlights the pros and cons of firebreaks and fuel breaks (or “fuelbreaks” as it is spelled in this publication). Several useful figures and photographs illustrate how to create firebreaks and fuel breaks near roads and structures. The link is to the web page for the book, Reducing Fire Risk on Your Property, where a link is provided to download a PDF of the chapter.

USDA NRCS. 2005. Fuel Break. Conservation Practice Standard 383. 2. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026161.pdf.

In this conservation practice standard, the USDA NRCS defines fuel breaks as land on which vegetation, debris, or detritus has been modified or reduced to control or reduce the spread of fire. The standard covers the purpose of the practice, conditions where it applies, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2012. Fuel Break. Conservation Standard Practice Overview 383. 1. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255017.pdf.

In this conservation practice standard overview, the USDA NRCS defines a fuel break and briefly describes where the practice is applied and other general considerations. A list of commonly associated practices is included: firebreaks, access roads, and forest trails and landings, as well as other practices associated with erosion control, grazing, and habitat management. The URL offers a direct download of a PDF of this resource.



A forest cut-over in North Carolina. Photograph by David Lindbo.

Self, A. B., and J. D. Kushla. 2016. Mechanical Site Preparation for Forestry in Mississippi. P3006. 8. Starkville, MS: Mississippi State University Extension Service. https://extension.msstate.edu/publications/publications/mechanical-site-preparation-for-forestry-mississippi.

This extension bulletin from the Mississippi State University Extension Service outlines the many mechanic site preparation operations needed prior to planting new trees. The emphasis is silviculture, but the practices mentioned can also be applied to other contexts. Covered topics include soil resources, mowing, shearing, chopping, disking, subsoiling, bedding, and combination plowing. Each practice is accompanied by an example figure.

USDA NRCS. 2006. Tree/Shrub Site Preparation. Conservation Practice Standard 490. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025998.pdf.

This conservation practice standard from the USDA NRCS begins by defining tree/shrub site preparation as treatment to improve site conditions for establishing trees and shrubs. The standard also includes information on the purpose of the practice, conditions where it applies, general criteria for implementing the practice, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2012. Tree/Shrub Site Preparation. Conservation Practice Standard Overview 490. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255112.pdf.

This conservation practice standard overview includes a definition of tree/shrub site preparation along with general information about the practice and additional considerations. It also includes a list of commonly associated practices: tree/shrub establishment, woody residue treatment, upland wildlife habitat management, and windbreak/shelterbelt establishment. The URL offers a direct download of a PDF of this resource.



A water quality tree planting in Kansas along a riparian area lost to flooding. Photograph by Jeff Vanuga, courtesy of the USDA NRCS.

Klempa, J. D. 2012. Tree Planting Guide. L596. 8. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=464&pubId=388.

This tree planting guide from the Kansas Forest Service outlines many considerations for planting conservation trees. Those include ordering conservation trees, planting time, care before planting, how to plant (hand planting, machine planting, and seed planting), and fencing. Many useful figures are included for each major concept.

USDA NRCS. 2016a. Tree/Shrub Establishment. Conservation Practice Standard 612. 5. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1255192&ext=pdf.

This conservation practice standard from the USDA NRCS defines tree/shrub establishment as the establishment of woody plants through natural regeneration or by planting cuttings, seedlings, or directly seeding. The standard outlines the purpose of tree/shrub establishment, describes conditions where it applies, criteria for implementing the practice, general considerations, plans and specifications, and operation and maintenance. Additional references are provided. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2016b. Tree/Shrub Establishment. Conservation Practice Standard Overview 612. 1. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026460.pdf.

This conservation practice standard overview for tree/shrub establishment includes a definition of the practice, along with general information for tree/shrub establishment. A list of commonly associated practices is provided, which includes tree/shrub site preparation, mulching, forest trails and landings, upland wildlife habitat management, and critical area planting, among others. The URL offers a direct download of a PDF of this resource.



Debris from fire break and fuel reduction project. Photograph by Gary Kramer, courtesy of the USDA NRCS.

Schnepf, C. C., R. T. Graham, S. Kegley, and T. B. Jain. 2009. Managing Organic Debris for Forest Health. 66. Moscow, ID: University of Idaho, Oregon State University, Washington State University. https://catalog.extension.oregonstate.edu/pnw609.

This Pacific Northwest Extension bulletin provides detailed information on managing organic debris. Information is presented on the impact of organic debris on inland northwest forest soils, management objectives for organic debris, strategies for managing fire, strategies for managing bark beetles, and strategies for managing wildlife. The bulletin is extensive but contains many useful figures and tables.

USDA NRCS. 2017a. Woody Residue Treatment. Conservation Practice Standard 384. 3. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1255018&ext=pdf.

In this USDA NRCS conservation practice standard, woody residue treatment is defined as treatment of woody residue created during natural disturbances or management activities. The standard also includes information on the purposes of the practice, conditions where it applies, criteria for its application, general considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2017b. Woody Residue Treatment. Conservation Practice Standard Overview 384. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1365411&ext=pdf.

In this conservation practice standard overview, the USDA NRCS defines woody residue treatment and provides general considerations for applying the practice. A list of commonly associated practices is provided and includes access control, critical area planting, firebreak forest stand improvement, integrated pest management, and prescribed burning. The URL offers a direct download of a PDF of this resource.



Angus cattle graze on the Gravelly Mountain Range in the Beaverhead-Deerlodge National Forest. Photograph courtesy of the USDA Forest Service.

Briske, D. D., ed. 2011. Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?&cid=stelprdb1045811.

This book from the USDA NRCS summarizes the findings from the Conservation Effects Assessment Project (CEAP) for rangeland. The URL links to a website with direct downloads to a standalone executive summary, as well as each chapter of the report. Practices discussed include prescribed fire, brush management, range planting, riparian management, impact of rangeland activities on wildlife, invasive plant management, landscape approaches to rangeland conservation practices, and social and economic assessment of rangeland conservation practices.

Butler, L., J. Cropper, R. Johnson, A. Norman, G. Peacock, P. Shaver, and K. Spaeth. 2003. National Range and Pasture Handbook. Fort Worth, Texas: USDA NRCS Grazing Lands Technology Institute. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084.

The National Range and Pasture Handbook provides procedures to support inventory, analysis, treatment, and management of grazing land resources to comply with USDA NRCS policy. The handbook includes information on grazing land resources, grazing land ecological sites and forage suitability groups, inventorying and monitoring resources, land management, animal nutrition, hydrology, wildlife management, enterprise diversification, economics, and conservation planning.

USDA NRCS. 2008. Forage Suitability Group Descriptions Fact Sheet. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043493.pdf.

This USDA NRCS fact sheet defines forage suitability groups as soil map unit components having similar potentials and limitations for forage production. The fact sheet also describes the importance of forage suitability groups and features of these groups.

USDA NRCS. 2019. Range & Pasture. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/rangepasture/.

The USDA NRCS range and pasture web page provides links to many related resources. It first defines range and pasture lands, then provides links to resources associated with ecological sites, forage suitability groups, technical references, and the National Grazing Lands Coalition.

Prescribed Grazing



Cattle graze in a rotational grazing system in Iowa. Photograph courtesy of the USDA NRCS.

USDA NRCS. 2017b. Prescribed Grazing. Conservation Practice Standard 538. 6. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255132.pdf.

In this conservation practice standard, the USDA NRCS defines prescribed grazing as managing the grazing and/or browsing of animals to comply with management, economic, or ecological objectives. The standard outlines purposes of the conservation practice, criteria for implementation, general considerations, plans and specifications, and operation and maintenance. No conservation practice standard overview is currently available for this practice. The URL offers a direct download of a PDF of this resource.

USFWS. 2009, February 18. Managing Invasive Pests – Management Methods: Prescribed Grazing. https://www.fws.gov/invasives/staffTrainingModule/methods/grazing/introduction.html.

This US Fish and Wildlife Service learning module provides a concise summary of prescribed grazing, followed by ways to test knowledge after completing the module. It has four parts: Introduction, Impacts, In Practice, and Review and Resource.

Prescribed Burning



A firefighter lights a prescribed burn with a drip torch. Photograph courtesy of the Tennessee Valley Authority.

Ohlenbusch, P. D., and D. C. Hartnett. 2000. Prescribed Burning as a Management Practice. L-815. 8. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=226&pubId=428.

This extension bulletin from Kansas State Research and Extension highlights various aspects and considerations for the use of prescription burns as a management practice on rangeland. Topics covered include benefits of prescribed burning, timing, forage yield, grazing distribution, livestock production, weed and brush management, wildlife, native grass, and wildfire hazard reduction. It also discusses effects on soil conditions and air quality.

USDA NRCS. 2010. Prescribed Burning. Conservation Practice Standard 338. 2. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026544.pdf.

In this USDA NRCS conservation practice standard, prescribed burning is defined as “controlled fire applied to a predetermined area”. The standard outlines the purposes of prescribed burning, criteria for its implementation, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2012. Prescribed Burning. Conservation Practice Standard Overview 338. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1254966.pdf.

In this conservation practice standard overview, the USDA NRCS defines prescribed burning, and provides a concise description of the practice and considerations for implementation. A list of associated conservation practices is provided, including forest stand improvement, forest trails and landings, range planting, and integrated pest management. The URL offers a direct download of a PDF of this resource.

USFWS. 2009. Managing Invasive Pests – Management Methods: Prescribed Burning. https://www.fws.gov/invasives/staffTrainingModule/methods/burning/introduction.html.

This US Fish and Wildlife Service learning module provides a concise summary of prescribed burning, followed by ways to test knowledge after completing the module. It has four parts: Introduction, Impacts, In Practice, and Review and Resource.

Brush Management



Implementation of brush management practices by the San Carlos Apache Tribe in Arizona. Photograph by Beverly Mosely, courtesy of the USDA NRCS.

Towne, G., and P. D. Ohlenbusch. 1992. Rangeland Brush Management. MF-1021. 4. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=226&pubId=524.

This extension bulletin from Kansas State Research and Extension describes how to remove trees and brush from rangeland to increase forage production and livestock carrying capacity. Considerations for management practices that can help in managing rangeland brush are provided: prescribed burning, mechanical removal, herbicides, and grazing management. The bulletin emphasizes that brush management is important for properly managing rangeland, and the key is to control potential problems before they become severe.

USDA NRCS. 2016. Brush Management. Conservation Practice Standard 314. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1254946.pdf.

In this USDA NRCS conservation practice standard, brush management is defined as the removal or management of woody plants including those that are invasive or noxious. The standard includes additional information on the purpose of brush management, the criteria and conditions where it applies, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.



A drill is used to plant rangeland. Photograph by Beth Newingham, courtesy of the USDA Forest Service.

Ohlenbusch, P. D. 1997. Establishing Native Grasses. 4. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=226&pubId=838.

This extension bulletin from Kansas State Research and Extension outlines considerations for establishing native grasses. Topics covered include planning for seeding, soils, seedbed preparation, seeding method, origin and quality of seed, seeding rates, seeding dates, fertilization, management during establishment, weed control, and management after establishment. A list of associated extension bulletins from Kansas State Research and Extension is included at the end.

USDA NRCS. 2010. Range Planting. Conservation Practice Standard 550. 3. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046903.pdf.

In this conservation practice standard, the USDA NRCS defines range planting as establishing adapted or self-sustaining vegetation like forbs, legumes, grasses, and trees and shrubs. The standard outlines purposes of range planting, along with additional information on conditions and criteria where the conservation practice applies, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2017. Range Planting. Conservation Practice Standard Overview 550. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255138.pdf.

In this conservation practice standard overview, the USDA NRCS defines range planting, then provides a concise summary of the conservation practice. A list of commonly associated conservation practices include brush management, grazing land mechanical treatment, prescribed burning, and prescribed grazing. The URL offers a direct download of a PDF of this resource.



A cow grazing in a silvopasture. Photograph courtesy of the USDA NRCS.

USDA National Agroforestry Center. 2019. Silvopasture. https://www.fs.usda.gov/nac/practices/silvopasture.php.

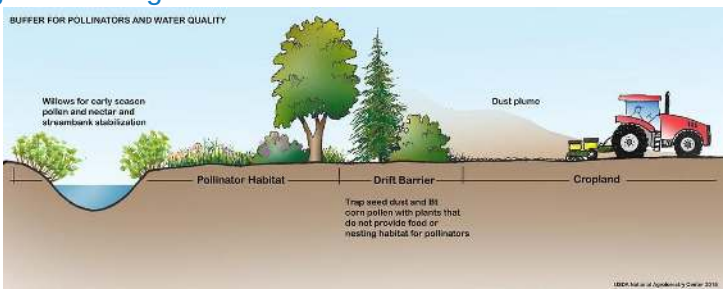
This web page from the USDA National Agroforestry Center defines silvopasture as “the integration of trees and livestock grazing on the same land.” The page also provides a concise summary of the practice, including some of the benefits. Links to additional resources are provided, including information sheets, brochures, agroforestry notes, and other resources. Links to an agroforestry continuing education course and agroforestry photos are also included.

USDA NRCS. 2016a. Silvopasture. Conservation Practice Standard 381. 5. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1255015&ext=pdf.

The USDA NRCS defines silvopasture as establishing trees and compatible forages on the same acreage in this conservation practice standard. The standard lists the purposes of silvopasture, states the conditions for where the practice applies, criteria for implementation, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2016b. Silvopasture. Conservation Practice Standard Overview 381.1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1053019&ext=pdf. The URL offers a direct download of a PDF of this resource.

This standard on the conservation practice of silvopasture defines silvopasture and provides a concise summary of the conservation practice. Conservation practices commonly associated with silvopasture establishment are listed, including tree/shrub preparation, forest stand improvement, tree/shrub establishment, tree/shrub pruning, forage and biomass planting, range planting, prescribed grazing, grassed waterway, and upland wildlife habitat management. The URL offers a direct download of a PDF of this resource.



Riparian forest buffer design for creating wildlife habitat and reducing pollinator pesticide exposure. Figure courtesy of the USDA National Agroforestry Center.

USDA National Agroforestry Center. 2019. Wildlife and Pollinators. https://www.fs.usda.gov/nac/topics/wildlife-pollinators.php.

This web page from the USDA National Agroforestry Center provides a concise summary of the role agroforestry can play in providing wildlife habitat for wildlife and pollinators. Links to additional resources are provided, including information sheets, brochures, agroforestry notes, and other resources.

USDA NRCS. 2010. Upland Wildlife Habitat Management. Conservation Practice Standard 645. 2. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025754.pdf.

The USDA NRCS defines upland wildlife habitat management as the practice of providing upland habitats and connectivity for wildlife within the landscape. The standard lists the purposes of upland habitat management, the conditions for the practice, criteria for implementation, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2012. Upland Wildlife Habitat Management. Conservation Practice Standard Overview 645. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255212.pdf.

This conservation practice standard overview defines upland wildlife habitat management and provides a concise summary of the conservation practice. Conservation practices commonly associated with upland wildlife habitat management are listed, among them watering facility, restoration and management of rare or declining habitats, and use exclusion.

USDA NRCS. 2019a. Fish and Wildlife Habitat Leaflets. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/plantsanimals/fishwildlife/pub/?cid=nrcs143_022362.

This web page includes links to wildlife habitat leaflets developed for many different animals and ecosystems. Each were developed in partnership with the Wildlife Habitat Council and are downloadable.

USDA NRCS. 2019b. Plants & Animals. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/plantsanimals/.

This USDA NRCS web page provides links to various plant and animal resources from the USDA and NRCS such as the PLANTS database.

USDA NRCS. 2019c. Wildlife Habitat Planting. Conservation Practice Standard 420. 5. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1460023&ext=pdf.

The USDA NRCS defines wildlife habitat planting as the practice of “establishing wildlife habitat by planting herbaceous vegetation or shrubs.” The standard lists the purposes of wildlife habitat planting states the conditions for where the practice applies, criteria for implementation, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2019d. Wildlife Habitat Planting. Conservation Practice Standard Overview 420. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1460023&ext=pdf.

This conservation practice standard overview defines upland wildlife habitat planting and provides a concise summary of the conservation practice. Practices commonly associated with wildlife habitat planting are listed and include herbaceous weed treatment, brush management, fence, and prescribed burning.

USDA NRCS Iowa. 2018. Iowa Native Prairie Planting Guide. 4. Des Moines, IA: USDA NRCS. https://www.nrcs.usda.gov/wps/cmis_proxy/https/ecm.nrcs.usda.gov%3a443/fncmis/resources/WEBP/ContentStream/idd_104EFC65-0000-C910-9983-4690C75DDB74/0/NativePlantingEst%26Mgmt.pdf.

This USDA NRCS publication covers establishing native prairie and managing native plantings. The focus is Iowa, but the information is relevant to other parts of the US. The guide includes directions for establishing native prairie plantings, controlling weeds after planting, prescribed burning, and haying and mowing. The guide emphasizes certain practices by years since establishment (first through third year and beyond). A burn schedule is provided for the state of Iowa, though these dates may vary for other regions. Other considerations are also described, such as control of Canada thistle and introduced grasses.

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2.4: Conservation Practices for Construction Sites and Disturbed Areas

Abbreviations

EPA- US Environmental Protection Agency
NRCS – Natural Resources Conservation Service
PAM – Polyacrylaminde
PDF – Portable Document Format
RUSLE – Revised Universal Soil Loss Equation
SWPPP – Stormwater Pollution Prevention Plan
URL – Uniform Resource Locator
US – United States
USDA – US Department of Agriculture

Erosion Control and Stormwater Pollution Prevention

US EPA. 2007. Developing Your Stormwater Pollution Prevention Plan. 50. Washington, D.C.: EPA. https://www.epa.gov/sites/production/files/2015-10/documents/sw_swppp_guide.pdf.

> This guide from the EPA is designed for construction site operators who control construction plans or supervise day-to-day construction site activities. The guide will help with developing a quality stormwater pollution prevention plan (SWPPP) and is applicable to any construction site required to comply with stormwater discharge requirements. The 50-page guide is divided into 9 chapters. Chapters 1 and 2 provide an overview and describe under what conditions an SWPPP is required. The guide then covers site assessment and planning; selecting erosion and sediment control best management practices; choosing good housekeeping best management practices; inspecting and maintaining an SWPPP as well as recordkeeping; certification and notification; implementation; and final stabilization and permit termination. The URL offers a direct download of a PDF of this resource.

US EPA. 2015, October 26. Developing a Stormwater Pollution Prevention Plan (SWPPP). https://www.epa.gov/npdes/developing-stormwater-pollution-prevention-plan-swppp.

> This web page contains links to resources for developing an SWPPP. It contains the SWPPP guide described above (EPA 2007), as well as example SWPPPs for various scenarios. Each are available as PDF downloads.

USDA NRCS. 2000. Erosion and Sedimentation on Construction Sites. 5. Auburn, AL: USDA NRCS Soil Quality Institute. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053285.pdf.

> This Urban Technical Note from the USDA NRCS Soil Quality Institute provides a brief description of erosion in the context of construction sites. This includes describing the on-site and off-site damage caused by erosion. The RUSLE model is described as an option for modeling erosion under different practices. The technical note also includes 13 principles for construction erosion control. The URL offers a direct download of a PDF of this resource.

Anionic Polyacrylamide Application

King, S., and R. McLaughlin. 2015. Fiber Check Dams and Polyacrylamide for Water Quality Improvement. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/fiber-check-dams-and-polyacrylamide-for-water-quality-improvement.

> In this Soil Facts extension bulletin from North Carolina State University, King and McLaughlin describe the use of fiber check dams as a best management practice for disturbed areas. It includes a spacing guide for fiber check dams of different sizes based on the slope of the channel. Maintaining fiber check dams is discussed, followed by information on reducing turbidity through the use of (Anionic Polyacrylaminde (PAM), a synthetic polymer that binds clays and fine silts to facilitate flocculation and settling of those particles.

McLaughlin, R. 2014. Chemical Turbidity Control in Pumped Construction Site Water. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/chemical-turbidity-control-in-pumped-construction-site-water.

> In this Soil Facts extension bulletin from North Carolina State University, McLaughlin provides an overview of techniques for reducing sediment in stormwater runoff from construction sites. Sediment basins and sediment bags are described, but McLaughlin states that these practices don't always reduce turbidity of stormwater runoff from

construction sites on clays and fine silts. McLaughlin then describes methods of dosing runoff using pump injection of PAM and solid PAM dosing using bricks or powder.

McLaughlin, R. 2015a. Chemical Treatment to Control Turbidity on Construction Sites. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/chemical-treatment-to-control-turbidity-on-construction-sites.

This extension bulletin from North Carolina State University highlights three types of chemical treatments used to reduce turbidity of stormwater runoff from construction sites. McLaughlin describes the use and effectiveness of PAM, gypsum ($CaSO_4$), and alum ($Al_2(SO_4)_3$), but PAM is the primary focus of this extension bulletin.

McLaughlin, R. 2015b. Using Polyacrylamide (PAM) to Reduce Erosion on Construction Site. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/using-polyacrylamide-pam-to-reduce-erosion-on-construction-sites.

In this Soils Facts extension bulletin from North Carolina State University, McLaughlin provides a concise summary of the properties of PAM and how it can be used on construction sites to reduce erosion. McLaughlin describes how PAM can be used to keep soil in place, typically be being applied to disturbed soil in conjunction with mulches and other types of groundcover.

USDA NRCS. 2016a. Anionic Polyacrylamide (PAM) Application. Conservation Practice Standard 450. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_026468&ext=pdf.

In this conservation practice standard, the USDA NRCS defines Anionic Polyacrylaminde (PAM) as a chemical that can be applied to soils to reduce erosion and increase infiltration rates. The USDA NRCS further describes the uses of PAM, the conditions under which it can be used, and the criteria that must be met for it to be used as a conservation practice. Ways in which PAM can be applied without risk to human health and the environment are also described. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2016b. Anionic Polyacrylaminde (PAM) Application. Conservation Standard Practice Overview. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1298028&ext=pdf.

In this conservation standard practice overview, the USDA NRCS describes how to use PAM to reduce irrigation-associated erosion or erosion on disturbed areas. A concise summary of general information on the practice is provided. Conservation practices commonly associated with PAM include sprinkler, surface, and subsurface irrigation. The URL offers a direct download of a PDF of this resource.

Diversion



A broad-based terrace forming the down slope ridge for a diversion channel directing water away from the cornfield below. Photo by Lynn Betts, courtesy of the NRCS.

USDA NRCS. 2009. Chapter 9 Diversions. In Engineering Field Handbook, 30. Washington, D.C.: USDA NRCS. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=25756.wba.

This chapter from the Engineering Field Handbook provides technical guidance for diversions that direct water downslope. The chapter begins with how to assess a site for its suitability for diversions. The chapter then outlines planning and preliminary design, design itself, installation, and maintenance of diversions.

USDA NRCS. 2016a. Diversion. Conservation Practice Standard 362. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1254995&ext=pdf.

This conservation practice standard from the USDA NRCS defines diversions as channels running across a slope with a ridge on the lower side. Diversions serve many purposes, but most relate to either interrupting water flow down a slope, or directing water to a desired location. The standard then outlines information on criteria for implementing the practice, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2016b. Diversion. Conservation Practice Standard Overview 362. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_026408&ext=pdf.

This conservation practice standard from the USDA NRCS defines diversions as channels running across the slope with a ridge on the lower side. The overview also contains concise, general information on the practice. Conservation practices commonly associated with diversions include grassed waterways, terraces, water storage facilities, and underground outlets. The URL offers a direct download of a PDF of this resource.

Mulching



A series of photographs of a culvert surrounded by a silt fence and other erosion control practices during construction, after final grade, and after a permanent grass cover is established in temporary straw mulch.

Babcock, D., and R. McLaughlin. 2008. Mulch Options for Erosion Control on Construction Sites. 5. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/mulch-options-for-erosion-control-on-construction-sites.

In this extension bulletin from North Carolina State University, Babcock and McLaughlin outline considerations for and effectiveness of three types of mulches: loose mulch, erosion control blankets, and hydraulically applied mulches (hydromulches). For each of the three mulch types, Babcock and McLaughlin state that long-term effectiveness depends on slope preparation and correct installation. In addition, site managers should consider soil preparation before establishing a seedbed for long-term cover.

USDA NRCS. 2017a. Mulching. Conservation Standard Practice 484. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1335267&ext=pdf.

In this conservation practice standard, the USDA NRCS defines mulching as applying plant residue or other materials to the soil surface. Mulching serves a variety of purposes, including improving moisture, reducing erosion, and improving efficiency of irrigation water. The standard outlines criteria for using this conservation practice, considerations for the practice, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2017b. Mulching. Conservation Standard Practice Overview 484. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1344016&ext=pdf.

In this conservation practice standard overview, the USDA NRCS defines mulching as applying plant residues and other substrates to the land surface. The overview includes information on why and when the practice should be used. Commonly associated practices listed in this overview include critical area planting, diversion, and establishing trees/shrubs and windbreaks/shelterbelts. The URL offers a direct download of a PDF of this resource.



A water control structure in a North Carolina ditch. Photograph by David Lindbo.

USDA NRCS. 2017a. Structure for Water Control. Conservation Practice Standard 587. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1335271&ext=pdf.

> In this conservation practice standard, the USDA NRCS defines a water control structure as a structure in a water management system that conveys water and controls the direction or rate of flow to maintain a desired water surface elevation or to measure water. The standard describes where the practice applies, criteria used for implementing the practice, considerations, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2017b. Structure for Water Control. Conservation Practice Standard Overview 587. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1349213&ext=pdf. The URL offers a direct download of a PDF of this resource.

> The USDA NRCS defined water control structures in this conservation practice standard overview as a structure in a water management system that conveys water and controls the direction or rate of flow to maintain a desired water surface elevation or to measure water. The overview also includes a concise description of how water control structures are used with other considerations. Conservation practices associated with water control structures and listed in this overview include dikes, subsurface drains, wetland restoration, and open channels. The URL offers a direct download of a PDF of this resource.



NRCS employees discuss the operation of the sediment basin behind them. Photograph by Bob Nichols, courtesy of the NRCS.

McLaughlin, R., and A. Jarrett. 2008. Surface Outlets for Sediment Basins. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/surface-outlets-for-sediment-basins.pdf.

This brief Soil Facts extension bulletin from North Carolina State University describes surface outlet skimmers for sediment basins. These are dewatering systems for sediment basins that function by removing the cleanest water from the surface of the basin while leaving water with the heaviest suspended sediment in the basin longer to allow additional sediment to fall out of suspension. Several pictures demonstrate the function of these skimmers. The bulletin closes with links to four resources related to sediment control basins. The URL offers a direct download of a PDF of this resource.

McLaughlin, R. 2015. Using Baffles to Improve Sediment Basins. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/using-baffles-to-improve-sediment-basins.

This extension bulletin from North Carolina State University outlines the use and types of baffles within sediment basins as a best management practice that decreases the sediment load in stormwater runoff. Baffles function by slowing the movement of water through the basin and converting turbulent water flow into laminar water flow. This allows sediment to settle out faster. Two types of baffles are described: solid baffles and porous baffles. Several figures and images show what these baffles look like, how they function, and how they are installed.

USDA NRCS. 2016a. Sediment Basin. Conservation Practice Standard 350. 4. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1254985&ext=pdf.

This conservation practice standard from the USDA NRCS defines sediment basins as basins with an engineered outlet, constructed using a dugout, an embankment, or both. The purpose of sediment basins is to capture sediment-laden runoff and debris long enough to allow settling within the basin. The standard goes on to describe where the practice applies, criteria for its implementation, considerations for the use of sediment basins, plans and specifications, and operation and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2016b. Sediment Basin. Conservation Practice Standard Overview 350. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcs143_026289&ext=pdf.

This conservation practice standard overview from the USDA NRCS defines sediment basins as basins with an engineered outlet, constructed using a dugout, an embankment, or both. The overview provides a brief description of the practice, where it applies, and how it is implemented. The overview also includes a list of commonly associated practices, including critical area planting, mulching, and structure for water control. The URL offers a direct download of a PDF of this resource.

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2.5: Rehabilitation of Problem Soils

Abbreviations

BMP – Best Management Practice
NRCS – Natural Resources Conservation Service
PDF – Portable Document Format
URL – Uniform Resource Locator
US – United States
USDA – US Department of Agriculture

Acid Soils

Crozier, C. R., and D Hardy. 2017. “Soil Acidity and Liming for Agricultural Soils.” Extension Bulletin AG-439-50. SoilFacts. Raleigh, NC: North Carolina State University. https://content.ces.ncsu.edu/soil-acidity-and-liming-for-agricultural-soils.

> This bulletin, published by the North Carolina State Extension Service, educates local producers about the benefits of using lime to reduce soil acidity. Crozier describes the naturally acidic conditions of soil in North Carolina and causes of soil acidity. This acidity can be corrected by liming soils. Crozier thus describes the benefits of liming soil and soil testing to determine liming rates, providing an example of how to calculate liming rates. Crozier also describes liming materials, making adjustments to application rates based on lime type, purity, and fineness, and other considerations for applying lime and using no-till.

Saline, Sodic, and Saline-sodic Soils



Salts accumulate at the highest point of a row in a flooded furrow irrigation system. Photograph courtesy of the NRCS.

Horneck, D.A., J.W. Ellsworth, D.M. Sullivan, B. Hopkins, and R. Stevens. 2007. “Managing Salt-Affected Soils for Crop Production.” PNW 601-E. A Pacific Northwest Extension Publication. Bend, Oregon, US: Oregon State University, Washington State University, University of Idaho. https://pubs.wsu.edu/ItemDetail.aspx?ProductID=15000&SeriesCode=&CategoryID=141&Keyword=.

> This Pacific Northwest Extension bulletin focuses on salts and salt-affected soils in the western US although the principles and concepts do apply in other regions. The authors begin by describing salts and the types of salt-affected soils: saline, sodic, and saline-sodic soils. They then summarize the various soil tests that can assess salinity and sodicity. Next, the authors explain how salt tolerance varies across crop species and how ion toxicity changes salt-affected soils. The bulletin ends with strategies for managing and reclaiming salt-affected soils, as well as a section on soil testing questions and answers.

McCauley, Ann, and Clain Jones. 2005. “Module 2 – Salinity and Sodicity Management 4481-2.” In Soil and Water Management, 16. Bozeman, MT: Montana State University. http://landresources.montana.edu/swm/.

The Montana State University Extension Service published this online module for extension agents, crop advisers, and local producers, providing an overview of the formation, symptoms, and management of salt-affected soils. The risk of salinization, or the accumulation of water-soluble compounds, increases with poor soil drainage, arid climate, poor quality irrigation water, and salt-containing soil amendments. There are three classes of salt-affected soils: saline, sodic, and saline-sodic. Each is characterized by different electrical conductivity, total dissolved solids, pH, and exchangeable sodium percentage. Plants in salt-affected soils undergo stress due to osmotic potential differences, damaged soil structure, and salt toxicity. Reclamation of salt-affected soils includes methods that flush land with irrigation water, add calcium- and magnesium-containing soil amendments, and plant salt-tolerant plants.

Ruiz Diaz, D., and D. Pressley. 2017. “Management of Saline and Sodic Soils.” MF-1022. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.k-state.edu/Item.aspx?catId=364&pubId=525.

In this Kansas State University Research and Extension publication, Ruiz Diaz and Presley review identification and reclamation of salt-affected soils. Soils characterized as saline, sodic, or saline-sodic are first described, followed by descriptions of soil tests for diagnosis, such as electrical conductivity and exchangeable sodium using an ammonium acetate extraction. Managing salt-affected soils is then discussed. Adjusting plant populations to salt- and sodium-tolerant crops is the most effective management practice for slightly- to moderately-affected soils. Soils more severely affected by salts and/or sodium must be treated using other strategies. Recommendations include chemical soil amendments, crop residue, and irrigation.

Compacted Soils

DeJong-Hughes, Jodi. 2014a. Soil Compaction (1st in Series). Soil Compaction. St. Paul, MN: University of Minnesota Extension Crops. https://www.youtube.com/watch?v=2TNqIrLe6J4.

In this extension video from the University of Minnesota, DeJong-Hughes reviews soil compaction and its negative effects on soil and crop health. DeJong-Hughes describes methods for limiting compaction: avoiding operating farm machinery under moist soil conditions, reducing axle load, properly inflating tires, properly sizing tires, and controlling wheel traffic. She also addresses a common myth that freeze-thaw cycles alleviate compaction from farm machinery and states that the weight of modern farm machinery causes compaction deep in the soil where freeze-thaw cycles do not occur frequently enough to break up compaction.

DeJong-Hughes, Jodi. 2014b. Soil Compaction: Proper Tire Inflation (4th in Series). Soil Compaction. St. Paul, MN: University of Minnesota Extension Crops. https://www.youtube.com/watch?v=dUbmeNYpcRI.

This University of Minnesota extension video demonstrates how proper tire inflation limits compaction and improves traction. Properly inflated tires have larger area of tire in contact with the soil, which distributes the axle load and limits the depth of compaction in the soil. Using the largest tire with the lowest tire inflation pressure will reduce potential compaction. The axle load can also be distributed over a larger area by using duals or triples, which increases the load capacity. New technologies that help operators manage tire pressures are also discussed.

DeJong-Hughes, Jodi. 2014c. Soil Compaction: Tracks and Tires (3rd in Series). Soil Compaction. St. Paul, MN: University of Minnesota Extension Crops. https://www.youtube.com/watch?v=fNsRFUWOqbo.

DeJong-Hughes describes the differences between tires and tracks in compaction in this extension video from the University of Minnesota. She explains that ground pressure for tires is very close to tire pressure, and that proper tire inflation depends on axle load, number of tires, and tire size. In contrast, ground pressure from tracks is calculated by dividing the weight on the tracks by the area of track in contact with the soil, though pressure spikes do occur immediately below the bogey wheels. DeJong-Hughs enumerates advantages to both tires and tracks and summarizes the advantages of each system. She then summarizes the practice of controlled wheel traffic, in which wheel or track traffic is restricted to the same paths across the field for as many field operations as possible. The final recommendation is to restrict grain cart traffic to paths already created by the combine or limiting erosion to endrows and keeping the carts off of the rest of the field.

DeJong-Hughes, Jodi. 2014d. Soil Structure: A Natural Defense against Soil Compaction (2nd in Series). Soil Compaction. St. Paul, MN: University of Minnesota Extension Crops. https://www.youtube.com/watch?v=HZDJ59Vf9lc.

In this extension video from the University of Minnesota, DeJong-Hughes explains why soil structure is important and how good structure can help resist compaction. Mycorrhizal fungi improve soil structure by producing glomalin, a glue that holds soil particles together. Strategies for encouraging these fungi and glomalin are reducing soil tillage, using crop rotation, leaving organic matter on the surface, or using cover crops. A slake test shows how to assess aggregate stability.

DeJong-Hughes, Jodi, John F. Moncrief, W. B. Voorhees, and J. B. Swan. 2001. “Soil Compaction: Causes, Effects and Control.” Extension Publication FO-3115-S. St. Paul, MN: University of Minnesota. http://hdl.handle.net/11299/55483.

This bulletin from University of Minnesota Extension Service reviews soil compaction. The authors present this information in sections, beginning with soil compaction causes and consequences, surface compaction, subsoil compaction, and control. Useful figures and diagrams are presented throughout the bulletin. The authors identify two types of compaction: surface and subsoil. Both types reduce soil moisture availability and nutrient uptake. Surface compaction can be remedied using tillage, but subsoil compaction is more difficult to resolve although it can be alleviated via subsoiling, split application of fertilizers, and/or reducing equipment traffic. To avoid compaction, wait for fields to dry before running equipment through them.

Duiker, Sjoerd W. 2002. “Diagnosing Soil Compaction Using a Penetrometer (Soil Compaction Tester).” Extension Publication 63. Agronomy Facts. State College, PA: Pennsylvania State University. https://extension.psu.edu/diagnosing-soil-compaction-using-a-penetrometer-soil-compaction-tester.

Duiker explains how a penetrometer can measure the extent of soil compaction in this extension bulletin from Pennsylvania State University. Penetrometers are instruments consisting of a steel shaft with a cone on the tip and a gauge on a handle that measures the amount of force necessary for the cone to penetrate the soil. Duiker states that penetrometer measurements should be taken approximately 24 hours following a rain event at a sampling rate of three to four measurements per acre. When penetration resistance exceeds 2000 kPa (300 psi), the compaction present can limit root growth. The percentage of readings that result in root-limiting conditions within 15 inches of the soil surface should be recorded. Fields with percentages of 30-50 are slightly compacted, 50-75 are moderately compacted, and more than 75% are severely compacted.



A handheld penetrometer being used in the field (left), associated equipment (top right), power meter (center right), and cones (bottom right). Photograph courtesy of HPsy.

USDA NRCS. 2015. Controlled Traffic Farming. Conservation Practice Standard 334. 3. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd340739&ext=pdf.

In this conservation practice standard, the USDA NRCS defines controlled traffic farming as the practice of "confining all high load wheel/track traffic from farm equipment to specific lanes or tramlines (traffic pattern) in crop fields year after year." This practice can improve soil health by limiting compaction due to wheel or track traffic and can be used where traffic can be limited to specific traffic lanes. The conservation practice uses specific criteria and considerations, with plans and specifications based on those criteria and considerations, followed by operations and maintenance. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2015. Controlled Traffic Farming. Conservation Practice Standard Overview 334. 1. Washington, D.C.: USDA. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd404636&ext=pdf.

This conservation practice standard overview should guide producers and USDA NRCS conservation planners as they implement BMPs. Controlled traffic farming requires confining heavy farm equipment traffic to specific lanes year to year. The goal is to limit heavy vehicle loads to those areas to reduce soil compaction. The benefits of controlled traffic farming include improved soil health, efficient use of nutrients, better yields, and higher soil water availability. The URL offers a direct download of a PDF of this resource.

USDA NRCS Soil Quality Institute. 2003. "Soil Compaction: Detection, Prevention, and Alleviation." Agronomy Technical Note 17. Soil Quality. Auburn, AL: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053258.pdf.

This technical note from the USDA NRCS Soil Quality Institute is an overview of soil compaction. In it, the Soil Quality Institute details the causes, detection, types, treatments, and prevention of soil compaction. Five types of compaction are defined: surface crusting, surface compaction, tillage pans, deep compaction, and inherent hardpans. Compaction can be measured using bulk density, tools like penetrometers, or field indicators like plant productivity and soil structure. To prevent soil compaction, the Soil Quality Institute encourages reducing equipment traffic and allowing fields to dry before working them. To remediate compaction, subsoiling is recommended. The URL offers a direct download of a PDF of this resource.

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2.6: Water Quantity and Quality Conservation

Abbreviations

EPA – US Environmental Protection Agency
NAWQA – National Water-Quality Assessment
NOAA – National Oceanic and Atmospheric Administration
NRCS – Natural Resources Conservation Service
PDF – Portable Document Format
SWCS – Soil and Water Conservation Service
URL – Uniform Resource Locator
US – United States
USDA – United States Department of Agriculture
USGS – US Geological Survey

Introduction to Hydrology



A USGS scientist collects stream discharge measurements in Valley Stream on Long Island, NY. Photograph courtesy of the USGS.

Earle, S. 2015a. Chapter 13 Streams and Floods. In Physical Geology. Victoria, BC: BCcampus. https://opentextbc.ca/geology/part/chapter-13-streams-and-floods/.

In this chapter from the open textbook, *Physical Geology*, Earle provides an overview of streams and floods. Topics covered include the water cycle, drainage basins, stream erosion and deposition, stream types, and flooding. Each section in the chapter concludes with a learning exercise.

Earle, S. 2015b. Chapter 14 Groundwater. In Physical Geology. Victoria, BC: BCcampus. https://opentextbc.ca/geology/part/chapter-14-groundwater/.

In this chapter from the open textbook, *Physical Geology*, Earle provides an overview of groundwater. Topics on groundwater include groundwater aquifers, flow, extraction, and quality. Each section in the chapter concludes with a learning exercise.

Easton, Z. M., and E. Bock. 2015. Hydrology Basics and the Hydrologic Cycle. 9. Blacksburg, VA: Virginia Polytechnic Institute and State University. https://pubs.ext.vt.edu/BSE/BSE-191/BSE-191.html.

In this extension publication from Virginia Tech, Easton and Bock describe the distribution of water around the world and then detail each component of the water (or hydrologic) cycle. They discuss how the various components interact and give rreferences for additional readings.

Heath, R. C. 1983. Basic Ground-Water Hydrology. 86. Reston, VA: US Geological Survey. https://doi.org/10.3133/wsp2220.

This USGS water supply paper provides a comprehensive introduction to groundwater. This includes the geology through which groundwater flows, a description of what affects groundwater flows and how to depict it, ways to characterize aquifers, how to properly install wells, and issues involving groundwater quality and pollution.

USDA NRCS. 2012, May. National Engineering Handbook – Part 630 – Hydrology. https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21422.

This 22-chapter NRCS publication covers in great detail the duties and responsibilities of hydrologists who work for the NRCS, describing different hydrologic tests and measurements they may be expected to perform, sources of data on different aspects of hydrology, and accuracy of different measurements.

Drainage



A tiling machine installed a flexible drainage tile line in a field near Fargo, ND. Photograph by Eric Brevik.

Ghane, E. 2018. Agricultural Drainage. Extension Bulletin E3370. 8. East Lansing, MI: Michigan State University Extension. https://www.egr.msu.edu/bae/water/drainage/agriculturaldrainage.

Ghane describes the history, need for, and types of agricultural drainage used in the state of Michigan in this Michigan State University extension bulletin. The concepts do apply to other areas. The bulletin covers subsurface drainage systems in great detail, including some informative figures showing how tile lines work. Surface drainage using drainage ditches is discussed briefly.

Pavelis, G. A. 1987. Farm drainage in the United States: History, status, and prospects. Washington, D.C.: US Department of Agriculture, Economic Research Service. https://eric.ed.gov/?id=ED295043.

Pravelis reviews the history of agricultural drainage in this USDA ERS publication, including the theory behind drainage, planning and engineering, and drainage economics. Drainage is also described within the context of federal programs that existed at the time of publication.

SWCS Events. 2018. Drainage Water Management: More Control and Greater Benefits for Your Field. Ankeny, IA: SWCS. https://vimeo.com/291575807.

This short (approximately 3 minute) video covers the basics of managed drainage using stop log structures. This technique allows land managers to control how much water is drained from agricultural land to either hold water back in a dry year, or prevent flushing nutrients out of the field following a big rain event.

Ward, A., and J. Witter. 2019. Agricultural Drainage. https://agditches.osu.edu/.

This website from The Ohio State University provides details on agricultural drainage using agriculture drainage channels (ditches), including descriptions of drainage ditch types that require different levels of management, case studies, tools and models. Links to and citations of extension fact sheets and peer-reviewed literature are included throughout the website.



Level furrow irrigation in a lettuce field in Yuma, AZ. Photograph by Jeff Vanuga, courtesy of the USDA NRCS.

Hopkins, B., D. A. Horneck, R. Stevens, J. W. Ellsworth, and D. M. Sullivan. 2007. Managing irrigation water quality for crop production in the Pacific Northwest. 29. Bend, Oregon, US: Oregon State University, University of Idaho, Washington State University. https://catalog.extension.oregonstate.edu/pnw597.

Hopkins et al. describe using water analyses to develop appropriate water management plans in irrigated agricultural systems in this Pacific Northwest Extension Publication. This includes the types of water tests to conduct, how to collect water samples, interpretating laboratory reports, and management options. They also discuss potential challenges in irrigated agriculture.

Rogers, D. H., J. Aguilar, I. Kisekka, P. L. Barnes, and F. R. Lamm. 2014. Soil, Water, and Plant Relationships. 8. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=363&pubId=491.

This extension publication is part of the Irrigation Management Series of publications from Kansas State University Research and Extension and provides an overview of soil, water, and plant relationships to aid producers in managing irrigation systems. Soil water content is discussed, as is soil water tension, soil texture, bulk soil density, and root depth. The authors emphasize how soil texture influences soil water-holding capacity, where plant roots obtain most nutrients and moisture, and how soil and water quality affects water uptake in plants.

USDA NRCS. 2001. Chapter 15 Irrigation. In Engineering Field Handbook, 60. Washington, D.C.: USDA NRCS. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17552.wba.

This chapter from the NRCS Engineering Field Handbook includes information for designing irrigation systems, describing the advantages of irrigation and what a successful irrigation system design requires. The chapter then details considerations in designing irrigation systems, basic design criteria, irrigation methods, water conveyance, land leveling, water disposal, equipment, measuring soil moisture, irrigation water management, irrigation scheduling, and more.



Drip irrigation lines in an orange orchard.

Presley, D., D. Shoup, J. Holman, and A. Schlegel, eds. 2012. Efficient Crop Water Use in Kansas. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=363&pubId=15559.

> This 44 page extension publication from Kansas State University includes seven brief chapters focused on practices for efficiently managing crop water use in Kansas. Those chapters focus on management practices including conservation tillage, residue management, use of specific center pivot irrigation nozzles, managing crop row spacing and orientation, nutrient management for water use efficiency, and weed control.

Rogers, D., P. L. Barnes, G. M. Powell, and K. Ebert. 2014. Irrigation Water. 8. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=363&pubId=16942.

> In this extension publication from Kansas State University Research and Extension, Rogers et al. describe the history of irrigation in the state of Kansas and trends in irrigation water use. Most of the irrigation water use is concentrated in the western third of the state, leading to severe depletion of the Ogallala and High Plains Aquifers in recent decades. The authors state that the economic importance of irrigation and lack of precipitation in western Kansas makes it unlikely that producers in the area will turn from irrigation. They further explain how irrigation water use efficiency and crop yield on irrigated land in western Kansas has improved over the last few years. These improvements are so far large enough to compensate for losses caused by decreased water levels in wells in certain areas.

Rogers, D. H., J. Aguilar, I. Kisekka, P. L. Barnes, and F. R. Lamm. 2015a. Agricultural Crop Water Use. 12. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=363&pubId=18185.

> In this extension publication, Rogers et al. describe the characteristics and controlling factors of crop water use and how crop water use can be measured at different time scales. They describe what causes variation in water use on diurnal, daily, and seasonal time scales. For seasonal water use, the authors describe how water use by a crop can compare to a reference crop in order to estimate evapotranspiration. The authors then describe how water use by crops can be normalized by the resulting yield produced and give a table of examples of various food items relative to how many

gallons were required to produce each food item. They further relate these relationships to irrigation and water use efficiency.

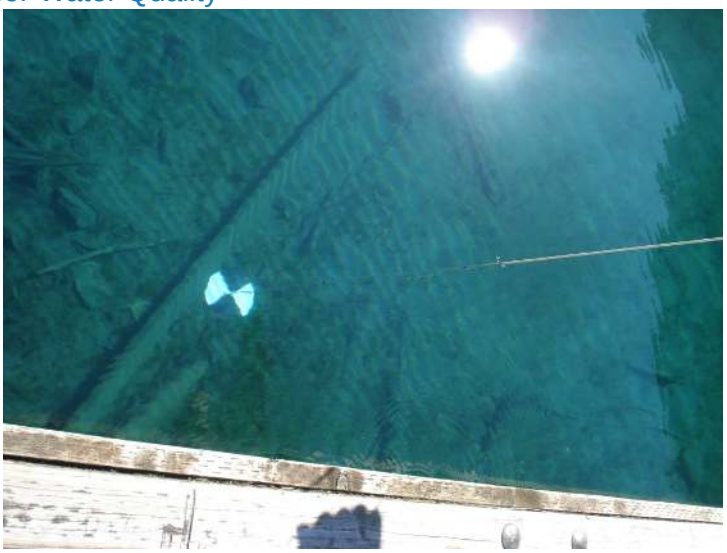
Rogers, D. H., J. Aguilar, I. Kisekka, P. L. Barnes, and F. R. Lamm. 2015b. Important Agricultural Soil Properties. 8. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=363&pubId=18183.

In this Kansas State University Research and Extension publication, Rogers et al. explain the relationship between soil properties and plant available water and how this relationship affects crop production. Soil texture, structure, series, density, and water content were discussed. Producers do not generally have the power to alter soil texture, but it is important to how much water a soil can hold. Soil structure and density are commonly altered by agricultural activities through compaction. Compacted soils have poor structure and high densities, thus decreasing the soil's capacity to retain water. Regardless of how much water a soil can hold, what is most important is the portion of the water that is available to plant roots, or plant available water. The portion of soil water is influenced by the porosity and texture of a soil.

Shock, C. C., B. M. Shock, and T. Welch. 2013. Strategies for Efficient Irrigation Water Use. 7. Corvalis, OR: Oregon State University. https://catalog.extension.oregonstate.edu/em8783.

In this Oregon State University extension bulletin, Shock et al. list and describe different approaches to efficient irrigation: avoiding over-irrigation, balancing water use with evapotranspiration, incorporating conservation tillage, and carefully managing water waste with surface sprinkler irrigation.

Managing Watersheds for Water Quality



Measuring water clarity with a Secchi disk in Lake Crescent, WA. Photograph by Eric Brevik.

Capel, P. D., K. A. McCarthy, R. H. Coupe, K. M. Grey, S. E. Amenumey, N. T. Baker, and R. L. Johnson. 2018. Agriculture — A River Runs Through It — The Connections Between Agriculture and Water Quality. 216. Reston, VA: USGS. http://pubs.er.usgs.gov/publication/cir1433.

This USGS report is one of a series of publications, *The Quality of Our Nation's Waters* that provides overviews of the major findings from the NAWQA program. This report is focused on the influence of agriculture on water quality. The report describes the following topics over nine chapters: the NAWQA studies on water quality and agriculture; an overview of water quality and agriculture; changes to agriculture over time in the US; terrain, climate, soil, and water; water on the pre-agriculture landscape; agricultural water and soil management; water on the agricultural landscape; chemicals in animal and crop agriculture; and connections between agriculture and water quality.

Crouse, D., J. Godfrey, R. McLaughlin, and D. L. Osmond. 2015. Soils and Water Quality. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/soils-and-water-quality.

Crouse et al. discuss the relationship between soil management and water quality in this North Carolina State University Extension publication. Management practices, or effects of management practices that impact soil and water quality discussed in this publication include soil erosion and sedimentation, runoff and leaching, household waste disposal, and land application of nutrient-laden organic materials. The bulletin concludes by emphasizing the importance of good soil management and the influence farmers can have in improving soil and water quality through conservation practices.

NOAA. 2017, July 6. Nonpoint Source Pollution. https://oceanservice.noaa.gov/education/tutorial_pollution/welcome.html.

This NOAA web page defines nonpoint source pollution as “pollution from sources that can’t be tied to a specific location” and shows it is not always the type of material but the concentration of a material that makes it a pollutant. Links lead to a tutorial in a downloadable PDF, as well as links to an extensive series of educational resources on nonpoint source pollution.

US EPA, O. 2015, February 12. Watershed Academy. https://www.epa.gov/watershedacademy.

The EPA’s Watershed Academy is a website designed for self-paced training on watershed management using online training modules, webcasts, and watershed management publications for educating interested parties in a variety of relevant watershed management topics. The modules and resources were designed for college freshman-level learners. Users can earn a “Watershed Academy Web Training Certificate” by completing 15 modules.

US EPA Office of Water. 2000. Big Darby Creek Case Study: A Profile of Watershed Threats and Protection in a Midwest Landscape. 37. Washington, D.C.: EPA. https://nepis.epa.gov/Exe/ZyPDF.cgi/20004K1S.PDF?Dockey=20004K1S.PDF.

The EPA investigated environmental threats and protection efforts, or lack thereof, for the Big Darby Creek and surrounding watershed in Ohio from the 1960s to 1990s. This case study, developed for the EPA’s Watershed Academy, summarizes that investigation, providing an introduction and a description of the watershed setting. The case study then provides a short history of recent developments and a description of threats to the watershed. Responses to those threats are then summarized, along with factors significant to the success of the responses. The case study closes with some final observations. The URL offers a direct download of a PDF of this resource.

US EPA Office of Water. 2019b, February 20. Agricultural Management Practices for Water Quality Protection. https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1362.

This online training module is one of several required modules in the Watershed Management Certificate Program. It is published by the EPA as part of its Watershed Academy. This module highlights and describes four principal agricultural management practices and four main nonpoint source pollution management methods. The practices and methods discussed include conservation tillage, crop nutrient management, pest management, conservation buffers, irrigation water management, grazing management, animal feeding operations management, and erosion and sediment control.

USDA NRCS. 2012a. Nutrient Management. Conservation Practice Standard Overview 590. 8. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1255175.pdf.

This NRCS conservation practice standard overview defines nutrient management as managing the timing, placement, and amount of plant nutrients to optimize yield and minimize risk of surface and groundwater pollution. The overview includes general information about nutrient management as a conservation practice and states that nutrient management is commonly associated with conservation practices aimed at mitigating erosion and reducing nutrient runoff. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2012b. Nutrient Management. Conservation Practice Standard 590. 8. Washington, D.C.: USDA NRCS. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046433.pdf.

This NRCS conservation practice standard overview defines nutrient management as managing the timing, placement, and amount of plant nutrients to optimize yield and minimize risk of surface and groundwater pollution. The standard includes further information on the purpose of the practice, along with conditions where it applies, criteria for the practice, general considerations, information for plans and specifications, and information on operation and maintenance. The URL offers a direct download of a PDF of this resource.



An urban stream in Seoul, South Korea.

Cappiella, K., W. P. Stack, L. Fraley-McNeal, C. Lane, and G. McMahon. 2012. Strategies for managing the effects of urban development on streams. 80. Reston, VA: US Geological Survey. http://pubs.er.usgs.gov/publication/cir1378.

This USGS report, one of a series of publications, *The Quality of Our Nation's Waters*, that provides overviews of the major findings from the NAWQA program. This report describes the following topics over seven chapters: a history of urban stream management, impacts of urban development, watershed management strategies to reduce the impact of urban development, and key challenges in managing urban development on streams.

Crouse, D., R. McLaughlin, and D. L. Osmond. 2015. Managing Lawns and Gardens to Protect Water Quality. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/managing-lawns-and-gardens-to-protect-water-quality.

Crouse et al. developed this North Carolina State University extension bulletin for homeowners wanting to reduce any environmental impact yard maintenance. They begin by explaining why water quality is a cause for concern. They then describe common sources of water pollution and ways to reduce water pollution. They explain that management of lawns and gardens should focus on reducing soil disturbance, increasing soil cover, and limiting nutrient and pesticide application. To reach these ends, practice the following: read pesticide and nutrient labels carefully; invest in alternatives to chemical pest management; avoid over-irrigation; and dispose of lawn and garden chemicals safely.

Freeborn, J. 2015. Decreasing Runoff and Increasing Stormwater Infiltration. 6. Blacksburg, VA: Virginia Polytechnic Institute and State University. https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/426/426-046/426-046-PDF.pdf.

In this extension publication from Virginia Tech, Freeborn explains how individual homes can contribute to stormwater runoff and practices that can decrease runoff from private residences. Freeborn begins with an example calculation of how much runoff can be generated by the impermeable surfaces of a single house. He then lists the practices that can be implemented on a single residence, including increasing permeability, directing water to more permeable areas, detaining water to allow infiltration, intercepting and holding rainwater, and using water on-site as needed. A variety of practices that can be used on already existing houses are then described, with photographs of each practice in place. The URL offers a direct download of a PDF of this resource.

US EPA Office of Water. 2019, February 20. 8 Tools of Watershed Protection in Developing Areas. https://cfpub.epa.gov/watertrain/moduleFrame.cfm?module_id=32&parent_object_id=1278&object_id=1278.

This online module published by the EPA outlines eight tools and practices that help protect watersheds and aquatic resources. The tools and practices include land use planning, land conservation, aquatic buffers, improved site design, stormwater best management practices, stewardship programs, non-stormwater discharge management, and sediment and erosion control. The goal of this module is to offer communities tools to sustainably protect the environment in developing

areas. The module is one of 15 in the Watershed Management Certificate Program, and is hosted on the EPA's Watershed Academy website.

USGS. 2019a. Urban Land Use and Water Quality. https://water.usgs.gov/edu/urbanquality.html.

This web page from the USGS provides a concise overview of the effects of urban land use on water quality. It covers water quality and ecology of small streams, streamflow alterations, effects of sealcoating on streams, effects of urban land use and groundwater quality, and pollution of lake and reservoir sediments from urban activities. Many links lead to related resources, including USGS pages for related topics and links to relevant publications from the USGS.

USGS. 2019b. Urbanization and Water Quality. https://water.usgs.gov/edu/urbanquality.html.

This web page from the USGS provides a concise overview of the effects of urbanization on water quality. It describes changes made and effects on watersheds related to initial urbanization, continued urbanization, and local communities taking steps to fix problems. Many links lead to related resources, including USGS pages for related topics and links to relevant publications from the USGS.

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CHAPTER OVERVIEW

3: Conservation Implementation

3.1: Conservation Practices in Broader Context

3.2: Conservation Agencies

3.3: Conservation Policies

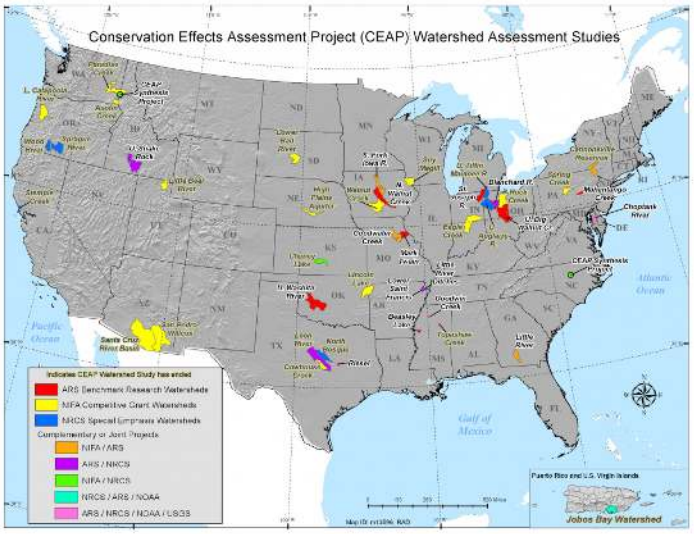
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3.1: Conservation Practices in Broader Context

Abbreviations

CEAP – Conservation Effects Assessment Project
IPCC – Intergovernmental Panel on Climate Change
EPA – US Environmental Protection Agency
NIFA – National Institute for Food and Agriculture
NRCS – Natural Resources Conservation Service
PDF – Portable Document Format
SWCS – Soil and Water Conservation Society
URL – Uniform Resource Locator
US – United States
USDA – US Department of Agriculture

The Conservation Effects Assessment Project



A map of the 42 watersheds assessed as part of CEAP. Map courtesy of the USDA NRCS.

Arabi, M., D. W. Meals, and D. Hoag. 2012. Lessons Learned from the NIFA-CEAP: Simulation Modeling for the Watershed-scale Assessment of Conservation Practices. 6. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/simulation-modeling-for-the-watershed-scale-assessment-of-conservation-practices.pdf.

> The CEAP was a multi-agency assessment project designed to quantify the effects of conservation practices, adopted by participating landowners in select USDA conservation programs, on the environment. This fact sheet summarizes lessons learned through CEAP and the use of simulation modeling for the assessment of conservation practices at the watershed scale. The URL offers a direct download of a PDF of this resource.

Hoag, D., A. E. Luloff, and D. L. Osmond. 2012. Lessons Learned from the NIFA-CEAP: How Farmers and Ranchers Make Decisions on Conservation Practices. 6. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/how-farmers-and-ranchers-make-decisions-on-conservation-practices.pdf.

> This fact sheet summarizes the lessons learned through CEAP about the considerations farmer and rancher use in adopting conservation practices, focusing on why farmers adopt conservation practices, the importance of profit, and other influences on the likelihood of adopting conservation practice. The URL offers a direct download of a PDF of this resource.

Jennings, G. D., D. Hoag, M. L. McFarland, and D. L. Osmond. 2012. Lessons Learned from the NIFA-CEAP: Effective Education to Promote Conservation Practice Adoption. 5. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/effective-education-to-promote-conservation-practice-adoption.pdf.

This fact sheet summarizes the lessons learned from CEAP conservation education and outreach programs. The fact sheet discusses the importance of community cooperation; using local points of contact to promote conservation practices, outreach program effectiveness; use of local organizations and nonprofits; and coordination of extension, USDA NRCS, and state conservation agencies. The fact sheet clarifies that education and behavior change should not be confused and that education alone cannot always change behavior. The URL offers a direct download of a PDF of this resource.

Meals, D. W., D. L. Osmond, D. Hoag, M. Arabi, A. E. Luloff, G. D. Jennings, M. L. McFarland, J. Spooner, A. N. Sharpley, and D. E. Line. 2012a. Lessons Learned from the NIFA-CEAP: Insights for Developing Successful Agricultural Watershed Products. 6. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/insights-for-developing-successful-agricultural-watershed-products.pdf.

This CEAP fact sheet provides insights and recommendations for developing watershed scale agricultural projects. It begins with a background on how some watershed scale government conservation programs were successful in improving water quality, many such programs were not successful. The authors describe several explanations for why results varied among programs. The lessons learned from CEAP are then synthesized into a protocol designed as a guideline for implementing watershed-scale conservation efforts to improve water quality. The URL offers a direct download of a PDF of this resource.

Meals, D. W., D. L. Osmond, J. Spooner, and D. E. Line. 2012b. Lessons Learned from the NIFA-CEAP: Water Quality Monitoring for the Assessment of Watershed Projects. 6. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/water-quality-monitoring-for-the-assessment-of-watershed-projects.pdf.

This CEAP fact sheet summarizes lessons learned from using water quality monitoring to assess watershed scale projects. The lessons learned focus on using previously collected data; detecting water quality responses to treatments through monitoring; designing and conducting water quality assessment in watershed projects; and how monitoring affects other project activities. The URL offers a direct download of a PDF of this resource.

Meals, D. W., A. N. Sharpley, and D. L. Osmond. 2012c. Lessons Learned from the NIFA-CEAP: Identifying Critical Source Areas. 7. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/identifying-critical-source-areas.pdf.

This CEAP fact sheet summarizes lessons learned from identifying critical pollutant source areas. Critical source areas are parts of watersheds where sediment sources coincide with active hydrologic transport mechanisms to move the pollutant downstream. These critical source areas often contribute a disproportionate amount of pollution within a watershed and should therefore be targeted for conservation practices. Methods used to identify critical source areas within CEAP watersheds are described, along with descriptions of other potential techniques. The factsheet concludes with a section on how to target critical source areas with conservation practices and why doing so is critically important for improving water quality. The URL offers a direct download of a PDF of this resource.

Osmond, D. L., and L. Duriancik. 2019. Synthesis Report: CEAP-NIFA Competitive Grant Watershed Studies. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/ws/?cid=stelprdb1047821.

The CEAP assessment project aimed to quantify the effects of conservation practices on the environment when adopted by participating landowners in select US Department of Agriculture (USDA) conservation programs. This webpage provides links to various CEAP resources, including project fact sheets, project summaries, a synthesis report, and other resources.

Osmond, D. L., D. Meals, A. Sharpley, M. McFarland, and D. Line. 2012a. Lessons Learned from the NIFA-CEAP: Conservation Practice Implementation and Adoption to Protect Water Quality. 6. Raleigh, NC: NC State University. https://content.ces.ncsu.edu/conservation-practice-implementation-and-adoption-to-protect-water-quality.pdf.

This fact sheet summarizes the lessons learned from adopting and implementing conservation practices intended to protect water quality. The fact sheet focuses on how conservation practice selection, timing, location, and relationships to other conservation practices influence water quality outcomes. Lessons learned were described as one part of implementing and maintaining conservation practices, controlling sediment, controlling nutrients, and the human dimension. The URL offers a direct download of a PDF of this resource.

Osmond, D. L., D. W. Meals, D. LK. Hoag, and M. Arabi, eds. 2012b. How to Build Better Agricultural Conservation Programs to Protect Water Quality: The National Institute of Food and Agriculture–Conservation Effects Assessment Project Experience.

Ankeny, IA: Soil and Water Conservation Society. http://www.swcs.org/resources/publications/how-to-build-better-agricultural-conservation-programs-to-protect-water-quality.

The aim of the CEAP assessment project was to quantify the effects of conservation practices on the environment as adopted by participating landowners in select USDA conservation programs. This book, produced by the SWCS, synthesizes information from CEAP assessments. Readers can navigate to an online version of each chapter in the book by clicking the book image or by using the links in the middle of the webpage. A link to a printable PDF version of the full book is also available.

SWCS. 2006. Final Report from the Blue Ribbon Panel Conducting an External Review of the US Department of Agriculture Conservation Effects Assessment Project. 26. Ankeny, IA: Soil and Water Conservation Society. http://www.swcs.org/resources/publications/blue-ribbon-panel-conducting-a-review-of-ceap.

As a partner in the implementation of the CEAP program, the SWCS was charged with facilitating an external review of CEAP. This 26 page SWCS report summarizes the findings of the external review. The objectives of the external review were to gather, analyze, and synthesize input from future users of CEAP to help the USDA formulate CEAP and related outputs and to recommend changes or new approaches to producing comprehensive assessments. The report includes a recommendation for a change of direction for CEAP, a blueprint for strategic resource management, recommendations for how to build the science base, and cautions.

SWCS. 2007. Conservation Provisions of the 2007 Farm Bill: Opportunities to Inform Debate. 12. Ankeny, IA: Soil and Water Conservation Society. http://www.swcs.org/resources/publications/conservation-provisions-of-the-2007-farm-bill.

In the early stages of the program, CEAP appointed a “Blue Ribbon Panel” to summarize the ability of CEAP to inform the 2007 Farm Bill debate over conservation. Members of the panel included conservation experts in academia and across federal agencies. This report, produced by the SWCS, summarizes the results of the Blue Ribbon Panel dialogue.

USDA NRCS. 2019. About CEAP. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014135.

This web page provides an overview of the CEAP program and serves as an index of key CEAP reports and publications. The page includes a description of the scope of CEAP, and a list of lead agencies, partner agencies, and additional partners. Additional links are provided to major products and reports that summarize findings produced through CEAP.

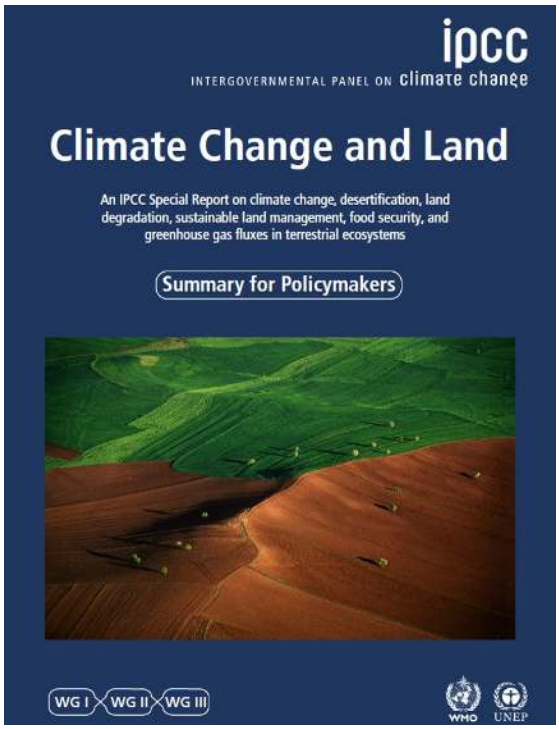
Conservation Practices and Climate Change

Brevik, E. C. 2012. Soils and Climate Change: Gas Fluxes and Soil Processes. Soil Horizons 53(4):12–23. https://dl.sciencesocieties.org/publications/sh/abstracts/53/4/12.

Increasing global temperatures and shifting precipitation patterns will affect the world’s soils, and those soils, in turn, will affect our atmospheric system. This review paper covers what we know about atmospheric-soil feedback of major greenhouse gases and ways that the changing climate will likely affect the resource. It also offers insights into needed research.

Shukla, P., J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, and J. Malley, eds. 2019. Climate Change and Land: an IPCC Special Report on Climate, Dessertification, Land Degradation, Sustainable Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/srccl/.

This is a special report by the IPCC and describes greenhouse gas fluxes from terrestrial systems, sustainable management strategies under a changing climate, and risks of desertification, land degradation, and food insecurity. It provides an update to previous similar reports.



Cover of the IPCC Report, *Climate Change and Land*, *Summary for Policymakers* from Shukla et al. (2019)

SWCS. 2003. Conservation Implications of Climate Change: Soil Erosion and Runoff from Cropland. 26. Ankeny, Iowa: Soil and Water Conservation Society. http://www.swcs.org/resources/publications/conservation-implications-of-climate-change.

This SWCS report focused on whether or not precipitation changes due to climate change would affect soil erosion and runoff from cropland. They concluded that conservationists should be seriously concerned about the effects of climate change on soil and water resources in the US.

US EPA. 2016, January 20. Understanding Climate Change Impacts on Water Resources. https://www.epa.gov/watershedacademy/understanding-climate-change-impacts-water-resources.

This online module from the EPA is designed to improve understanding of the causes of climate change, the potential effects on water resources, and the challenges faced by water resource managers. The module is broken into three parts: climate change 101, building resiliency of water resources to climate change, and exploring your region. The module is designed for college freshmen and should take approximately 45 minutes to complete.

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3.2: Conservation Agencies

Abbreviations

ARS – Agricultural Research Service
BIA – Bureau of Indian Affairs
BIE – Bureau of Indian Education
BLM – Bureau of Land Management
DOI – Department of the Interior
EPA – US Environmental Protection Agency
FAO – Food and Agriculture Organization of the United Nations
NACD – National Association of Conservation Districts
NCSS – National Cooperative Soil Survey
NIFA – National Institute of Food and Agriculture
NPS – National Parks Service
NRCS – Natural Resources Conservation Service
PDF – Portable Document Format
SCS – Soil Conservation Service
SES – Soil Erosion Service
UN – United Nations
URL – Uniform Resource Locator
US – United States
USACE – US Army Corps of Engineers
USDA – US Department of AgricultureUSFS – US Forest Service
USFWS – US Fish and Wildlife Service
USGS – US Geological Survey

Conservation Districts



Farmers attending a training in Champaign County in Illinois organized by the local Soil and Water Conservation District. S.T.A.R. stands for Saving Tomorrow's Agriculture Resources, and is an evaluation system used to assign points for each cropping, tillage, nutrient application, and soil conservation practice used on individual fields. Photograph by Erin Bush.

NACD. 2019a. About Districts. https://www.nacdnet.org/about-nacd/about-districts/.

NACD created this web page to depict the primary purpose of a conservation district: "to coordinate assistance from all available sources – public and private, local, state and federal – to develop locally-driven solutions to natural resource concerns." Almost every county in the US has a conservation district, a total of almost 3,000 districts. The exact services that districts provide to members are also found on this web page.

NACD. 2019b. About NACD. https://www.nacdnet.org/about-nacd/.

In this web page, NACD provides an overview of their organization. NACD is a nonprofit organization comprising more than 17,000 governing officials that coordinate conservation efforts in nearly 3,000 conservation districts across the US. Their work consists of publishing information from research and news to distribute to the members of their districts, providing various services to members, and working with the people at the local, state, and federal levels to promote conservation practices. Their mission is “to promote the wise and responsible use of natural resources for all lands representing locally-led conservation districts and their associations through grassroots advocacy, education and partnerships.”

NACD. 2019c. Hall of Distinction. https://www.nacdnet.org/about-nacd/nacd-history/hall-of-distinction/.

This web page created by NACD is dedicated to the five most influential district official leaders in NACD’s history. These individuals shaped effects and the direction of conservation districts in the US. Their information and accomplishments are found under the picture of each individual.

NACD. 2019d. NACD History. https://www.nacdnet.org/about-nacd/nacd-history/.

This NACD web page provides details on the history of conservation districts, as well as how the NACD came about. Inspired by the devastation of the Dust Bowl, President Franklin Delano Roosevelt pushed for soil conservation districts to be adopted across the nation to prevent such catastrophic events. The NACD was originally founded by 18 representatives from 17 states in 1946. The names of the founding members, along with their pictures, are also provided on this page.

Land Grant Colleges and Universities



Savanna Crossman, a soil scientist from Kansas State University, a Land-grant University, determines soil color in a dynamic soil properties research project. Photograph by DeAnn Presley.

Association of Public Landgrant Universities. 2019. Land-Grant University FAQ. https://www.aplu.org/about-us/history-of-aplu/what-is-a-land-grant-university/.

This Association of Public Landgrant Universities web page defines the term “Land-Grant University” and explains why they were created, where they are, who oversees the institutions, and when the Land-Grant Act passed.

Obama, B. 2012, July 2. Morrill Act 150th Anniversary – Message from the President. https://www.usda.gov/sites/default/files/documents/morrill-act-150-anniversary-president-message.pdf.

This announcement from President Obama in honor of the 150th anniversary of the signing of the Morrill Act recognizes the legacy of the Land-Grant system and the impact Land-Grant colleges and universities have had on the US. The URL offers a direct download of a PDF of this resource.

USDA National Agricultural Library. 2019, February 10. Morrill Land Grant College Act. https://www.nal.usda.gov/morrill-land-grant-college-act.

This web page features the text of the Morrill Land Grant College Act, as well as a link to a photocopy of the act from the Library of Congress.

USDA NIFA. 2019. Land-Grant Colleges and Universities. https://nifa.usda.gov/land-grant-colleges-and-universities.

This USDA NIFA web page lists all Land-Grant colleges and universities in the US by state and territory.

National Cooperative Soil Survey



A map of soil colors of the continental US. The data used to produce this map is from the collective soil mapping efforts by the NCSS. Map by Dylan Beaudette, courtesy of the USDA NRCS.

USDA NRCS. 2019. National Cooperative Soil Survey. https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/partnership/ncss/

This site explains the structure of the National Cooperative Soil Survey (NCSS). The NCSS is a nationwide partnership of federal, regional, state, and local agencies and private entities and institutions. This partnership works to cooperatively investigate, inventory, document, classify, interpret, disseminate, and publish information about soils. NCSS standards are common or shared procedures that enhance technology transfer, data sharing, and communication among soil survey participants.

Gardner, D. R. 1998. The National Cooperative Soil Survey of the United States. Cambridge: The National Cooperative Soil Survey of the United States and Harvard University. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044424.pdf.

This thesis was written by Gardner for his doctor of public administration from Harvard University. It was originally published in 1957 and was later reprinted by the USDA NRCS to facilitate broader distribution and readership. The 276 page thesis provides an exhaustive review of the history of the NCSS, written by Gardner who had prior experience as a soil scientist with the SCS (now USDA NRCS). In his thesis, Gardner describes the origins of the soil survey, history of the soil survey from 1899-1952, the coordination of the NCSS, and the NCSS since 1952. The URL offers a direct download of a PDF of this resource.

NCSS. 2016. National Cooperative Soil Survey Strategic Plan. 7. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1134606&ext=pdf.

The NCSS Strategic Plan outlines the NCSS vision, mission, and goals. It also lists objectives and action items for the strategic planning committee. Members of the strategic planning committee are listed on the final page of the plan. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2019. National Cooperative Soil Survey. https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/partnership/ncss/.

This USDA NRCS web page is the primary web page for the NCSS. It includes links to the NCSS Strategic Plan, and to Parts 600, 601, and 602 of the National Soil Survey Handbook, which guides the operation of the cooperating organizations in the NCSS. The page also includes links to NCSS conferences, newsletters, contact information, and other useful information.

USDA NRCS. 2017b. Part 601 – National Cooperative Soil Survey Organization Subpart A – General Information. In Title 430 – National Soil Survey Handbook, 601-A.1-601-A.4. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=41513.wba.

This section of the National Soil Survey Handbook defines the National Cooperative Soil Survey as a nationwide partnership of federal, regional, state, and local agencies as well as private entities that cooperate to investigate, inventory, document, classify, interpret, disseminate, and publish information on soils of the US. The section outlines the responsibilities of the NCSS, the USDA NRCS, and other cooperating agencies and organizations in conducting soil surveys of the US.

USDA NRCS. 2019b. The National Cooperative Soil Survey (NCSS). http://nrcs.maps.arcgis.com/apps/Cascade/index.html?appid=90b5990ab2b24b78b1968ed70a53817a.

This ArcGIS story map website describes what the NCSS is and what it does. Information on how to find out more about the NCSS is also provided through a link to the full NCSS website. This website provides an excellent overview of the NCSS with great pictures and brief text.

Tennessee Valley Authority



The Pickwick Landing Dam. Photograph courtesy of the TVA.

TVA. 2018. TVA at a Glance. 2. Knoxville, TN: Tennessee Valley Authority. https://www.tva.gov/file_source/TVA/Site%20Content/About%20TVA/TVA%20at%20a%20Glance.pdf.

This two-page information sheet about the TVA summarizes the mission of the TVA and the role it plays in energy and environmental and economic development for the people of the Tennessee River Valley. It also summarizes the service area served by the TVA and describes how the agency is funded.

TVA. 2019a. About TVA. https://www.tva.gov/About-TVA.

This TVA web page describes the TVA is a corporate agency of the US. The agency is self-funded and derives revenue from the sale of hydroelectric power. It also provides flood mitigation and land management, operating in Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia. This page includes links to more information about the agencies activities in each of those states, as well as a link to download a two-page “TVA at a Glance” information sheet about the agency. Links are also provided to more information about the agency’s leadership, advisory councils, history, and more.

TVA. 2019b. Our History. https://www.tva.gov/About-TVA/Our-History.

This TVA web page outlines the history of the agency dating back to the passage of the TVA Act of 1933. Each decade since is briefly summarized, with a link to a page with more information on TVA history from each decade. Links are also provided to the TVA Act, as well as to a comprehensive bibliography of TVA history.



Two ARS researchers watch a rainfall simulation being used to improve the WEPP model used to predict erosion. Photograph by Scott Bauer, courtesy of the USDA ARS.

USDA ARS. 2019a, March 20. Organizational Chart. https://www.ars.usda.gov/people-locations/organizational-chart/.

This web page displays an organizational chart of the USDA ARS. The USDA ARS Office of the Administrator oversees central program planning, administration and support, and field research implementation and information delivery. USDA ARS offices and regional field laboratories are listed.

USDA ARS. 2019b, April 30. History of Research at the USDA and ARS. https://www.ars.usda.gov/oc/timeline/chron/.

This web page includes a timeline of the 150+ year history of the USDA ARS dating back to 1862 when the USDA ARS was founded. Hyperlinks for each decade lead to pages that list each of the major discoveries of USDA ARS researchers, along with pictures of many of the discoveries for each period.

USDA ARS. 2019c, June 25. ARS Administrator's Council. https://www.ars.usda.gov/oc/agency/ac/admcouncil/.

This web page displays the name, title, and portrait of each of the USDA ARS administrators, national program staff, area and National Agricultural Library, headquarters staff, and other agency leaders. A downloadable version of the council is also available.

USDA ARS. 2019d, August 2. About ARS. https://www.ars.usda.gov/about-ars/.

This page from the USDA ARS website describes the USDA ARS as the "chief scientific in-house research agency" within the USDA. The page also includes the agency's mission statement, vision statement, and core values. Additional information about the agency leadership, research, budgeting, and partnership is provided. The page also identifies the USDA ARS as one of four USDA Research, Education, and Economics mission areas, along with USDA NIFA, USDA ERS, and USDA NASS.

USDA ARS. 2019e. Plans & Reports. https://www.ars.usda.gov/docs/plans-reports/.

The USDA ARS web page provides brief descriptions of and links to the USDA ARS Strategic Plan and the most recent USDA ARS Science Report.



A USDA FSA program technician meeting with a fruit and vegetable farmer in Iowa. Photograph by Preston Keres, courtesy of the USDA FSA.

USDA FSA. 2019b. About FSA. https://www.fsa.usda.gov/about-fsa/index.

This web page contains links to information about the effects of the USDA FSA, its structure and organization, biographies, strategic plan, history and mission, budget and performance, and careers.

USDA FSA. 2019c. Agency History. https://www.fsa.usda.gov/about-fsa/history-and-mission/agency-history/index.

This web page presents a synopsis of the history of the USDA FSA and outlines the functions of the agency and changes over time. The USDA FSA was formed in 1933 during the Great Depression as a part of President F. D. Roosevelt's New Deal. It was originally called the Resettlement Administration but was later renamed the Farm Service Agency in 1937. Its purpose was to relocate entire farm communities to areas where farming could be carried out more profitably. They also had programs to provide credit, farm and home management planning, and technical supervision, just to name a few.

USDA FSA. 2019d. History and Mission. https://www.fsa.usda.gov/about-fsa/history-and-mission/index.

This web page lists the USDA FSA mission statement, agency vision, societal vision, and values. The USDA FSA's mission is to equitably serve "all farmers, ranchers, and agricultural partners through the delivery of effective, efficient agricultural programs for all Americans."

USDA FSA. 2019e. Strategic Plan. https://www.fsa.usda.gov/about-fsa/strategic-plan/index.

The most recent USDA FSA strategic plan can be downloaded from a link on this web page. The fiscal year 2016-2018 strategic plan includes a message from the administrator followed by an overview, mission and vision statements, core values, external risk factors, and four strategic goals.

USDA FSA. 2019f. Structure and Organization. https://www.fsa.usda.gov/about-fsa/structure-and-organization/index.

This web page presents the organization of the USDA FSA. The agency reports to the Secretary of Agriculture and the Undersecretary of Agriculture for Farm and Foreign Agricultural Services. The national administration is in Washington, D.C., with computational and statistical work in Kansas City, MO. Farm policy and USDA FSA programs are implemented through state and 2,124 field offices based in counties throughout the country and US territories. The web page states that an organizational chart is impending.



USDA Forest Service crew member working to clear the understory of a timber stand to improve growth and wildlife habitat in Beaverhead-Deerlodge National Forest in Montana. Photograph by Preston Keres, courtesy of the USDA.

Forest History Society. 2019. US Forest Service Headquarters Collection. https://foresthistory.org/research-explore/us-forest-service-history/.

This web page from the Forest History Society highlights the USFS Headquarters. The page includes links to notable figures, places, policy and law, publications by the department, and a database to search all of these categories.

Los Padres National Forest. 2019. History & Culture. https://www.fs.usda.gov/main/lpnf/learning/history-culture.

This web page from the Los Padres National Forest details the history and culture of the USFS. The page concisely covers the who, what, when, where, and why of the entire USFS.

National Archives and Records Administration. 1985. Visions of the Wild. https://archive.org/details/gov.archives.arc.13521.

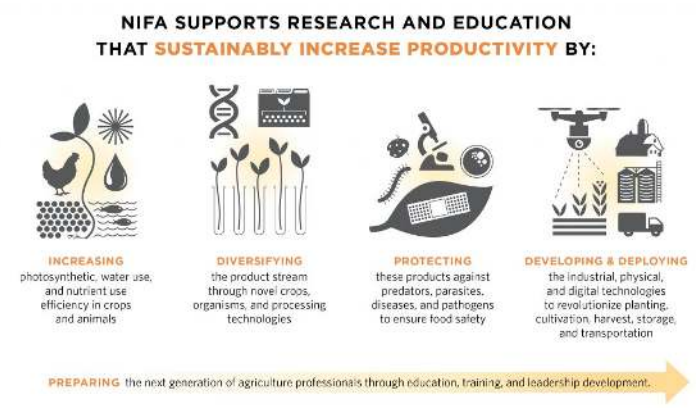
In this video, Peter Thomas recounts the beginnings of the US wilderness movement and its transformation into the USFS. The history, goals, and mission of the early administration are covered in depth in this 57 minute documentary.

USDA Forest Service. 2019. National Accomplishment Reports. https://www.fs.fed.us/visit/passes-permits/reports.

This USFS web page provides links to reports summarizing accomplishments of the USFS as presented to Congress. National reports are produced every three years. Additional regional reports are also provided.

Williams, G. W. 2005. USDA Forest Service: The First Century. Washington, D.C.: USDA Forest Service Office of Communication. https://www.fs.fed.us/sites/default/files/media/2015/06/The_USDA_Forest_Service_TheFirstCentury.pdf.

Written by the USFS historian, this book documents and analyzes the first 100 years of the agency. Williams organized the 100 years into nine periods. For each period, major events, notable people, and notable legislation and regulation are summarized. The table of contents also identifies locations of many notable special topics within the nine listed periods. The URL offers a direct download of a PDF of this resource.



An infographic showing how USDA NIFA supports research and education in agriculture. Graphic by Stephanie Engle, courtesy of USDA NIFA.

USDA NIFA. 2019a. About NIFA. https://www.nifa.usda.gov/about-nifa.

This site summarizes the responsibilities and goals of USDA NIFA. The site outlines what USDA NIFA is, what it does, and how it works. A USDA NIFA fact sheet is provided at the end.

USDA NIFA. 2019. Impacts. https://www.nifa.usda.gov/impacts.

This web page provides links to the USDA NIFA Annual Report, the USDA NIFA Fresh From the Field bulletin, and highlights from USDA NIFA-funded research. A search box allows quick searches by keyword, priority area, or US state and territory.

USDA NIFA. 2019b. NIFA Fact Sheet. https://www.nifa.usda.gov/resource/nifa-fact-sheet.

This one-page fact sheet answers questions about USDA NIFA, which is the primary extramural funding agency of the USDA. The agency invests in research related to agriculture, education, and extension. The fact sheet identifies and summarizes the nine priorities of USDA NIFA. It also lists the USDA NIFA mission and vision statements and summarizes its annual budget.

USDA NIFA. 2019. Programs. https://www.nifa.usda.gov/programs.

This web page provides a brief description of and links to web pages for each of the USDA NIFA funding programs. A search feature is provided to quickly identify appropriate programs.



Hugh Hammond Bennett, first Chief of the US SCS (now USDA NRCS), pointing at rills eroded into a bare hillside.

Helms, D. 2008. Hugh Hammond Bennett and the creation of the Soil Conservation Service. Journal of Soil and Water Conservation 65(2):37A-47A. http://www.jswconline.org/content/65/2/37A.full.pdf+html.

This article is a continuation of the historical developments discussed in "Hugh Hammond Bennett and the creation of the Soil Erosion Service," *Journal of Soil and Water Conservation*, Volume 64, Number 2, pages 68A-74A. The article discusses the events of September 19, 1933, to April 27, 1935, during which time Hugh Hammond Bennett and colleagues in the SES established demonstration projects. The SES was the precursor to the SCS (now the USDA NRCS).

USDA NRCS. 2019a. About NRCS. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/about/.

This USDA NRCS web page summarizes the agency's role in providing farmers, ranchers, and forest managers with free technical assistance to voluntarily put conservation on the ground. The page provides quick access to pages detailing getting started, technical assistance, financial assistance, locating service centers, tools and resources, news, and USDA NRCS history.

USDA NRCS. 2019b. Campaigns. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/newsroom/?cid=stelprdb1260106.

This web page highlights examples of the agencies activities. Campaigns include unlock the secrets of soil, this American land, strike force, backyard conservation, agriculture advisors, and conservation in your community. Each icon is a hyperlink to a page with more information on the campaign.

USDA NRCS. 2019c. More Than 80 Years Helping People Help the Land: A Brief History of NRCS. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/about/history/?cid=nrcs143_021392.

This article provides a brief history of USDA NRCS from its beginnings as the SES, its transformation into the SCS, and its current form, the USDA NRCS. For more than 80 years, the USDA NRCS has been a pioneer in conservation, working with landowners, local and state governments, and other federal agencies to maintain healthy and productive working landscapes.

USDA NRCS. 2019d. Organization. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/about/org/.

This web page provides the organizational structure of the NRCS starting at the national level, then covering state offices, service centers, and national centers.

USDA NRCS. 2019e. Programs. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/.

This site describes the USDA NRCS's conservation programs that help land managers reduce soil erosion, enhance water supplies, improve water quality, increase wildlife habitat, and reduce damage caused by floods and other natural disasters.

US Department of Defense

US Army Corps of Engineers



A wetland restored by the USACE. Photograph by Nathan R. Beane, courtesy of the USACE.

USACE. 2019a. Brief History of the Corps. https://www.usace.army.mil/About/History/Brief-History-of-the-Corps/.

This web-based publication summarizes the history of the USACE from its formation by the Continental Congress in 1775 through present day. Congress's goal was for the agency to contribute to both military and civilian projects. This web page provides a concise history of the USACE and notes key functions of the agency in the 1900s.

USACE. 2019b. Civil Works. https://www.usace.army.mil/Missions/Civil-Works/.

This web page outlines the civil missions of the USACE. This includes serving the public; developing and managing the nation's waterways; supporting commercial navigation; restoring, protecting, and managing aquatic ecosystems; managing flood risk; and providing engineering and technical services. The page includes links to the Civil Works Strategic Plan, Civil Works Program Stakeholder Satisfaction Report, and other resources and reports. A side menu contains links to pages on all civil works missions.

USACE. 2019c. Environmental. https://www.usace.army.mil/Missions/Environmental/.

This USACE web page summarizes all aspects of the Environmental Program, which includes cleaning up contaminated sites, cleaning up radioactive waste, supporting the EPA superfunds program, supporting the Army with the Base Realignment and Closure Act program, ensuring facility compliance with environmental laws, and conserving cultural and natural resources.

USACE. 2019d. Leadership. https://www.usace.army.mil/about/leadership/.

This web page provides an overview of the leadership of the USACE, with pictures and biographies provided for each officer.

US Department of the Interior

Bureau of Indian Affairs

Bureau of Indian Affairs. 2019a. About Us. https://www.bia.gov/about-us.

This web page from the BIA website summarizes the history and missions of the BIA and the BIE. The web page states that the BIA is the oldest agency in the DOI. The agency provides services to 1.9 million American Indians and Alaska Natives and their communities through grants, contracts, and compacts.

Bureau of Indian Affairs. 2019b. Bureau of Indian Affairs (BIA). https://www.bia.gov/bia.

This web page presents the mission statement and history of the BIA. Its mission is “to enhance the quality of life, to promote economic opportunity, and to carry out the responsibility to protect and improve the trust assets of American Indians, Indian tribes and Alaska Natives.” It goes on to state how and why the BIA was developed. It also includes the 45 people who have served as Commissioners of Indian Affairs and the 12 people who have served as the Assistant Secretary-Indian Affairs.

Bureau of Indian Affairs. 2019c. Division of Forestry and Wildland Fire Management. https://www.bia.gov/bia/ots/dfwfm.

This web page summarizes services provided by the BIA Division of Forestry and Wildland Fire Management. The page includes overviews of the division, the Branch of Forest Resource Planning, and the Branch of Wildland Fire Management. Links to websites of those two branches are provided.

Bureau of Indian Affairs. 2019d. Division of Natural Resources. https://www.bia.gov/bia/ots/division-natural-resources.

This web page summarizes services provided by the BIA Division of Natural Resources through that division’s three branches, the Branch of Agriculture and Rangeland Development; the Branch of Fish, Wildlife, and Recreation; and the Branch of Water Resources. Links are provided for each branch’s web page.

Bureau of Indian Affairs. 2019e. Indian Affairs Organizational Chart. Bureau of Indian Affairs. https://www.indianaffairs.gov/sites/bia.gov/files/OrgChartFY18Greenbook.pdf.

This document is the organizational chart of Indian Affairs. The Assistant Secretary-Indian Affairs and the Principal Deputy Assistant oversee all dealings within the BIA and BIE. Each office and region are listed as well as who oversees them. The URL offers a direct download of a PDF of this resource.

Bureau of Indian Affairs. 2019f. Programs and Services. https://www.bia.gov/programs-services.

This web page highlights all programs and services that the BIA provides to 567 federally recognized tribes. These programs serve to assist Indian self-governance and self-determination by improving their tribal government structure, community structure, education, job training, and employment opportunities.

Bureau of Land Management



A road sign for the BLM-managed Sandy Ridge Trail System, a bike park that provides mountain biking opportunities in the Foothills of the Cascade Mountains. Photograph by Michael Campbell, courtesy of the BLM.

BLM. 2016a, July 19. About Overview. https://www.blm.gov/about.

This web page summarizes the BLM, its history, leadership, organization, budget, mission, laws and regulations, what land agency manages, how the agency manages that land, and more.

BLM. 2016b, August 10. About: History of the BLM. https://www.blm.gov/about/history.

This BLM web page provides an overview of the agency’s history from its origins from the General Land Office and US Grazing Service which oversaw and allotted public lands during the country’s expansion west. The BLM was created by the Truman administration in 1946 to manage the public lands that remained under federal control. It’s charge is defined

by the Federal Land Policy and Management Act of 1976, which gives the BLM two mandates, to manage the public land for multiple uses, and to manage grazing on public lands.

BLM. 2016c, August 15. About: Organization Chart. https://www.blm.gov/about/organization-chart.

This web page presents the organizational chart for the BLM. The BLM is headquartered in Washington D.C. and employs approximately 10,000 people.

BLM. 2018. Our Public Land Heritage: From the GLO to the BLM. BLM. https://www.blm.gov/sites/blm.gov/files/About_historytimeline.pdf.

This BLM web page provides an overview of the agency's history from its origins from the General Land Office and U.S. Grazing Service, which oversaw and allotted public lands during the country's expansion west. The BLM was created by the Truman administration in 1946 to manage the public lands that remained under federal control. Its charge is defined by the Federal Land Policy and Management Act of 1976, which gives the BLM two mandates: to manage the public land for multiple uses and to manage grazing on public lands. The URL offers a direct download of a PDF of this resource.

Bureau of Reclamation

Bureau of Reclamation. 2019a. Facts. https://www.usbr.gov/main/about/fact.html.

This web page is a fact sheet that describes the Bureau of Reclamation, highlights the agency's priorities, and identifies its current activities. The page includes a table that summarizes a variety of different topics by number.

Bureau of Reclamation. 2019b. Mission. https://www.usbr.gov/main/about/mission.html.

This web page states that the mission of the Bureau of Reclamation is to "manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public." It begins with a brief history of the agency, followed by a description of its role as the largest water wholesaler in the US and its role in producing hydroelectric power. The page includes a map highlighting the states in which the bureau operates as well as links to the strategic plan.

National Parks Service



Sunrise over Theodore Roosevelt National Park in North Dakota. Photograph courtesy of the NPS.

NPS. 2009, September 17. Evolution of an Idea. https://www.nps.gov/americasbestidea/templates/timeline.html.

This web page was created by the NPS for a general audience looking for information on the history of the NPS. The origins and some of the major land accumulation/park opening events are briefly covered. The page also includes a history slide show with minor events, visitor information, and pictures. The history of the NPS shows how long land conservation has been an evolving idea.

NPS. 2019, September 11. What We Do. https://www.nps.gov/aboutus/index.htm.

This web page was created by the NPS for an audience with general interest in the NPS. A mission statement is available as well as small sections on employees, organization, and other general information about the NPS. Each section is a short overview with links provided to direct readers to more detailed information about that section. This overview of the NPS gives generic information about the NPS and what its charge is.

US DOI. 2016, August 17. Turning 100: Major Milestones in the National Park Service. https://www.doi.gov/blog/turning-100-major-milestones-national-park-service.

This blog was created by the DOI for a general audience interested in the major accomplishments of the NPS. While the focus is accomplishments, the page also includes information on the origins and history of the NPS and some notable people. The text has links embedded leading readers to other articles related to topics on this page. The blog emphasizes the role of the NPS in soil and water conservation through conserving the national parks.

WETA, and The National Parks Film Project, LLC. 2009. The National Parks: America's Best Idea. http://www.pbs.org/nationalparks/.

This website for the documentary series, The National Parks: America's Best Idea, provides a range of resources on the National Parks System, many of which complement the content of the documentary series. The site includes information about the history of the parks, parks highlighted in the documentary, important people, resources for educators, and more.

US Fish and Wildlife Service



Waterfowl at Quivira National Wildlife Refuge in Kansas. Photograph by Dan Severson, courtesy of the USFWS.

USFWS. 2018a, March 30. USFWS History: A Timeline for Fish and Wildlife Conservation. https://training.fws.gov/history/USFWS-history.html.

Considered the oldest federal conservation agency, FWS can trace its roots to 1871 to the creation of the U.S. Commission on Fish and Fisheries. This timeline covers 143 years (1871-2014) of events, acts, and processes that have been affected or implemented by the FWS. Example events include creating the FWS, appointing new FWS Directors, and passing the Duck Stamp Act. This resource is provided by the Natural Conservation Training Center and is suitable for those hoping to find a detailed outline of historical events associated with the FWS.

USFWS. 2018b, October 16. About the US Fish and Wildlife Service. https://www.fws.gov/help/about_us.html.

The FWS is a federal agency charged with the conserving, protecting, and enhancing habitats for fish, wildlife, and plants for the benefit of the American people. The FWS is housed within the DOI and was formed in 1940 by consolidating the Bureau of Fisheries and the Bureau of Biological Survey. Objectives of the FWS include helping develop and implement environmental stewardship for fish and wildlife, guiding conservation management practices for fish and wildlife within the US, and the administering programs to educate the public on fish and wildlife resources.

USFWS. 2019, July 17. National Organizational Chart. https://www.fws.gov/OFFICES/orgcht.html.

Updated on a regular basis, this page outlines the organizational structure of the U.S. Fish and Wildlife Service and provides links to the web page for each division housed within. The general outline for the USFWS starts with the Deputy Director, who is supported by a series of assistant directors each of whom oversee a series of divisions. Each assistant director is aided by a deputy assistant director. The US is a vast territory to cover, so eight regional directors are also included. Regions include Pacific, Southwest, Midwest, Southeast, Northeast, Mountain-Prairie, Alaska, and Pacific Southwest. Regional directors report to the Deputy Director.

US Geological Survey



USGS scientists sampling for suspended-sediment concentration on the Rio Grande River. Photograph courtesy of the USGS.

Rabbitt, M. C. 2019, September 30. US Geological Survey Circular 1050–The United States Geological Survey: 1879-1989. https://pubs.usgs.gov/circ/c1050/.

This web page is the table of contents for a web book detailing the history of the USGS. The history is divided into sixteen different eras by chapter.

USGS. 2019a. About Us. https://www.usgs.gov/about/about-us.

This web page provides a brief summary of the purpose of the USGS. It also contains links to pages with more detailed information regarding the purpose, history, and organization of the USGS.

USGS. 2019b. Key Officials. https://www.usgs.gov/about/key-officials.

This web page lists the USGS directors and the years of their terms as director. A link is provided to a biography page for each of the directors. A link to an organizational chart shows how various responsibilities are broken down among key officials.

USGS. 2019c. Organization. https://www.usgs.gov/about/organization.

This web page provides an index of information on the organization of the USGS. There are links to individual pages about mission areas, science centers, regions, and science support. There is also a link to a map showing the different regions in the current USGS organization.

USGS. 2019d. Who We Are. https://www.usgs.gov/about/about-us/who-we-are.

This web page provides a brief overview of the mission, vision, and goals of the USGS.

US Environmental Protection Agency



The EPA Headquarters. Photograph courtesy of the EPA.

Lewis, J. 1985. The Birth of EPA. EPA Journal 11 (November 1985):6. https://archive.epa.gov/epa/aboutepa/birth-epa.html.

This EPA Journal article chronicles the events and socio-political ideologies leading to the EPA's creation in 1970. Lewis describes the increased environmental consciousness in the 1960s. Rachel Carson's "Silent Spring" discussed the use of pesticides that sparked environmental controversy. President Nixon formed several environmental committees. Eventually, in 1970, the Nixon administration created the EPA as a conglomerate of regulatory government groups, creating a new government agency. The EPA's initial missions were to establish and enforce environmental protection standards, conduct environmental research, provide assistance to those combating environmental pollution, and assist the Council of Environmental Quality in developing and recommending to the President new policies for environmental protection.

US EPA. 2017, January 10. Timeline of Major Accomplishments in Transportation, Air Pollution, and Climate Change. https://www.epa.gov/transportation-air-pollution-and-climate-change/timeline-major-accomplishments-transportation-air.

This EPA web page provides a unique timeline of the agency's major accomplishments as they relate to transportation, air pollution, and climate change from 1970 until the 2010s. Starting in 1970, the EPA played a crucial role in passing the initial Clean Air Act, requiring a 90% reduction in emissions by 1975. Air pollution milestones in the 1980s include amendments to the Clean Air Act and fuel volatility limits aimed at reducing evaporative emissions. The 1990s and 2000s brought more amendments to the Clean Air Act and continued regulation for the automobile industry.

US EPA. 2019, August 27. About EPA. https://www.epa.gov/aboutepa.

This EPA web page presents the mission of the EPA as well as information about the EPA administrator; headquarters offices; office of inspector general; regional offices; research centers, programs, and science advisory organizations; offices with a geographic focus; planning, budget, and results; and working with the EPA. A map of all EPA facilities around the US is provided as well as a box with featured resources like the EPA organizational chart, history, newsroom, and more.

International Conservation Agencies

Food and Agriculture Organization

FAO. 2019a. About FAO. http://www.fao.org/about/en/.

This web page provides an overview of the FAO, which is an agency of the United Nations focused on defeating hunger. It includes an interactive timeline that has videos highlighting notable historical events with short videos.

FAO. 2019b. Conservation Agriculture. http://www.fao.org/conservation-agriculture/en/.

This web page from the FAO highlights conservation agriculture practices. The page includes a definition of conservation agriculture, a fact sheet, and related links. Tabs on this page include an overview, impact, case studies, resources, news,

and more.

FAO. 2019c. 2015 International Year of Soil. http://www.fao.org/soils-2015/en/.

The year 2015 was declared the International Year of Soils by the 68th UN General Assembly. The FAO implemented the celebration within the framework of the Global Soil Partnership in collaboration of governments and the secretariat of the UN Convention to Combat Desertification. This website dedicated to the 2015 International Year of Soil includes many resources designed to increase awareness of the importance of soil.

FAO. 2019d. Food and Agriculture Organization of the United Nations. http://www.fao.org/home/en/.

The FAO website provides a wealth of information about the FAO and the resources it provides to the world. This homepage provides highlights, data, main topics, publications, country showcases, and more.

FAO. 2019e. Sustainable Development Goals. http://www.fao.org/sustainable-development-goals/en/.

This web page is an overview of the FAO Sustainable Development Goals. It includes news, information for each of the 17 goals, highlights of partnerships, information on how progress is tracked, and indicators used.

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3.3: Conservation Policies

Abbreviations

ARS – Agriculture Research Service
CAFO – Confined Animal Feeding Operation
CDC – Center for Disease Control
EPA – US Environmental Protection Agency
FQPA – Food Quality Protection Act
NPDES – National Pollutant Discharge Elimination System
NPS – National Park Service
PDF – Portable Document Format
SARA – Superfund Amendments and Reauthorization Act
URL – Uniform Resource Locator
US – United States
USACE – US Army Corps of Engineers
WOTUS – Waters of the United States

Clean Air Act



Smog over the city of Los Angeles skyline in 1973. Photograph by Gene Daniels, courtesy of the US EPA.

US EPA. 2015d, May 29. The Clean Air Act in a Nutshell: How It Works. https://www.epa.gov/clean-air-act-overview/clean-air-act-nutshell-how-it-works.

> This overview of the Clean Air Act explains how it addressed pollution problems and summarizes key cross-cutting provisions. Topics include hazardous air pollutants, visibility in national parks, acid rain, stratospheric ozone layer, pollution causing climate change, operating permits, enforcement, relationships to state clean air laws.

US EPA. 2015a, February 27. Overview of the Clean Air Act and Air Pollution. https://www.epa.gov/clean-air-act-overview.

> This website provides an overview of the Clean Air Act. It includes access to the full text of the act, an overview of how it works and is enforced, its history, and achievements since the act was passed in 1963.

US EPA. 2015b, May 27. Clean Air Act Requirements and History. https://www.epa.gov/clean-air-act-overview/clean-air-act-requirements-and-history.

> In 1970, Congress voted the Clean Air Act into law. The act requires the EPA to establish air quality standards based on the latest science. The EPA must monitor and reduce criteria air pollutants, pollutants that can harm health and environment and cause property damage. Congress made major revisions in 1977 and 1990 to address regional haze, acid rain, and the depletion of the ozone layer as well as other air pollution problems.

US EPA. 2015c May 29. Clean Air Act Text. https://www.epa.gov/clean-air-act-overview/clean-air-act-text.

This EPA web page includes an introduction to the Clean Air Act, followed by a table of contents to each of the six titles within the act with links to the text of each title.

The Clean Water Act



Algae bloom in a small farm pond. Photo courtesy of SoilScience.info.

EPA Office of Water. 2019, February 20. Introduction to the Clean Water Act. https://cfpub.epa.gov/watertrain/moduleFrame.cfm?module_id=69&parent_object_id=2569&object_id=2569.

This learning module from the EPA Watershed Academy provides an overview of the Clean Water Act. The module was designed for watershed managers but is relevant to broader audiences as well. The module includes 78 slides and links to relevant resources like the full text of the Clean Water Act. The module is one of 15 required for those interested in being certified in watershed management.

Mulligan, S. P. 2019. Evolution of the Meaning of "Waters of the United States" in the Clean Water Act. 42. Washington, D.C.: Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R44585.

This report from the Congressional Research Service written for members of Congress provides an overview of the term Waters of the United States (WOTUS), as it has been interpreted by all three branches of government over time.

Rogers, D. H. 2013. Water Primer: Part 5, Water Law. 8. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. https://www.bookstore.ksre.ksu.edu/Item.aspx?catId=363&pubId=15859.

This extension publication from Kansas State University covers water law that governs groundwater and surface water use in the state of Kansas. It covers the Kansas Water Appropriation Act, the Kansas Groundwater Management District Act, interstate compacts, water rights, federal water policy, and environmental laws affecting water.

USACE, and US EPA. 2015. Definition of "Waters of the United States," 80 Fed. Federal Register 80(124):37054–37127. https://www.federalregister.gov/documents/2015/06/29/2015-13435/clean-water-rule-definition-of-waters-of-the-united-states.

This Federal Register publication is the text of the 2015 Clean Water Rule as proposed by the US EPA and USACE during the Obama administration.

USACE, and US EPA. 2019. Revised Definition of "Waters of the United States." Federal Register 84(31):4154–4220. https://www.federalregister.gov/documents/2019/02/14/2019-00791/revised-definition-of-waters-of-the-united-states.

This Federal Register publication is the text of the 2019 Clean Water Rule as proposed by the US EPA and USACE during the Trump administration.

US EPA. 2013, February 22. History of the Clean Water Act. https://www.epa.gov/laws-regulations/history-clean-water-act.

This web page from the EPA provides a brief history of the Clean Water Act. It also includes links to the text of the Clean Water Act, a summary of the act, and more.

Regulation of Wetlands

Gatz, L., and M. Stubbs. 2017. Wetlands: An Overview of Issues. 28. Washington, D.C.: Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R44585.

> This report from the Congressional Research Service written for members of Congress provides an overview of issues related to wetland regulation. The report summarizes wetland science, selected federal wetlands programs, state protection programs, and wetland restoration and mitigation.

Johnson, S. M. 2015. Wetlands Law: A Course Source. The Center for Computer-Assisted Legal Instruction eLangdell Press. https://open.umn.edu/opentextbooks/textbooks/wetlands-law-a-course-source.

> This course source on wetlands law serves as a textbook for law students and covers all aspects of wetlands law in the US. It is an open-access textbook. Chapters cover the science; history of regulation; administrative law; regulations of waters of the US; additions and discharges; section 404 permits; mitigation; EPA's role; state roles and programs; appeals, review, and enforcement; and regulatory takings.

The National Pollutant Discharge Elimination System

US EPA. 2014, November 3. Supplemental Module: NPDES Permit Program. https://www.epa.gov/wqs-tech/supplemental-module-npdes-permit-program.

> This learning module from the EPA Watershed Academy provides an overview of the NPDES. It is designed for watershed managers but is relevant to broader audiences as well. The module covers all aspects of the permitting process. The module is one of 15 required for those interested in being certified in watershed management.

US EPA. 2014, August 6. National Pollutant Discharge Elimination System (NPDES). https://www.epa.gov/npdes.

> This is the home web page for the NPDES; the system was formed as part of the Clean Water Act to regulate point-source pollution discharges to Waters of the United States. The page provides links to information about the NPDES, program areas, and technical resources.

Concentrated Animal Feeding Operations



Hog confinements in Wisconsin. Photograph by Bob Nichols, courtesy of the USDA NRCS.

Hribar, C. 2010. Understanding Concentrated Animal Feeding Operations and Their Impact on Communities. 30. Bowling Green, OH: National Association of Local Boards of Health. https://www.cdc.gov/nceh/ehs/docs/understanding_cafos_nalboh.pdf?fbclid=IwAR3DK7qlkmPsTg6D8CGoDnrLQfjOvvkekIP34AHQvD47ugqTR9RvwDOmqpU.

> This CDC sponsored manual explores the specifications, history, and benefits of CAFOs. It then summarizes environmental health effects that CAFOs have on groundwater, surface water, air quality, greenhouse gas emissions, climate change, odors, insect vectors, pathogens, antibiotics, and property values. This overall review of CAFOs further provides case

studies reviewing right-to-farm laws and Board of Health involvement. Regulatory definitions are also provided for small, medium, and large CAFOs.

Overcash, E. 2011. Detailed Discussion of Concentrated Animal Feeding Operations. https://www.animallaw.info/article/detailed-discussion-concentrated-animal-feeding-operations.

This legal summary covers the basic definitions of CAFOs and then reviews the definition, conditions, and locations of CAFOs. Animal, environmental, and human concerns arising from CAFOs are discussed. Legislation is broken into federal laws, state animal welfare measures, and subjects of CAFO measures. Finally, pending legislation concerning CAFOs are presented.

US EPA Office of Water. 2010. Implementation Guidance on CAFO Regulations – CAFOs That Discharge or Are Proposing to Discharge. 15. Washington, D.C.: US EPA. https://www3.epa.gov/npdes/pubs/cafo_implementation_guidance.pdf.

This EPA publication provides guidance on implementing the 2008 CAFO rule on how to comply with the regulations. It provides an overview of regulatory requirements, discusses the key elements of an objective assessment, and covers all animal sectors including the dairy, beef cattle, swine, and poultry sectors. Waste storage and handling, mortality management, and land application areas are also covered in this publication. The URL offers a direct download of a PDF of this resource.

USDA NRCS. 2019a. Animal Feeding Operations. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/plantsanimals/livestock/afo/.

This NRCS overview covers the specifications for an animal feeding operation to qualify as a CAFO. It also explores how the NRCS can assist a producer to better comply with CAFO regulations. Comprehensive Nutrient Management Plans (CNMP) are also covered in detail along with guidance documents and handbooks. Feed management for CAFOs is the final point discussed.

USDA NRCS. 2019b. Animal Feeding Operations – Publications. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/plantsanimals/livestock/afo/pub/.

This USDA NRCS web page provides links to various government publications relevant to animal feeding operations. Topics include animal management, manure and waste management, feed management, and pathogen management.

The Farm Bills

Conway, K. M. 2018. H.R.2 – 115th Congress (2017-2018): Agriculture Improvement Act of 2018. https://www.congress.gov/bill/115th-congress/house-bill/2/text.

The most recent farm bill, the Agriculture Improvement Act of 2018, can be viewed on this web page on Congress.gov. The lead sponsor was Representative Conway. Tabs on the page indicate a summary, text, actions, titles, amendments, and related bills, among others.

Johnson, R., and J. Monke. 2019. What is the Farm Bill? 17. Washington, D.C.: Congressional Research Service. https://fas.org/sgp/crs/misc/RS22131.pdf.

This brief from the Congressional Research Service written for members of Congress provides an overview of the farm bill which includes a history of the farm bill in a timeline and a pie chart depicting money allotted to each section of the bill. The brief summarizes each of the 12 sections in the most recent farm bills. A new farm bill is typically passed once every five to six years. The URL offers a direct download of a PDF of this resource.

The National Agricultural Law Center. 2019. United States Farm Bills. https://nationalaglawcenter.org/farmbills/.

This web page from the National Agricultural Law Center lists all the farm bills in the history of the US. Links are provided to each of the bills via Congress.gov where each farm bill can be read. The National Agricultural Law Center was created by Congress in 1987 and receives funding through appropriations from the USDA ARS National Agricultural Library.

USDA NRCS. 2019. Farm Bill. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/farmbill/.

This web page from the USDA NRCS lists and summarizes conservation programs included in the 2018 farm bill. It also includes a link to download the brochure, “Farmers’ Guide to 2018 Farm Bill Programs” as a PDF. Links to additional farm bill programs and other resources are also included at the bottom of the page.

The Food Quality Protection Act

US EPA. 2006, August 3. Accomplishments under the Food Quality Protection Act (FQPA). https://archive.epa.gov/pesticides/regulating/laws/fqpa/web/html/fqpa_accomplishments.html.

This web page highlights accomplishments achieved through the Food Quality Protection Act through 2006 for the ten years since the law was passed with bipartisan support in 1996. The page presents challenges in implementing and comprehending the pesticide and food safety laws. The FQPA changed many safety regulations and evaluated pesticide risks involving infants and children. The web page also states that other protective measures were required to assess aggregate effect on the exposure to pesticides in food and water. Reassessments have been constant ever since the act was passed in 1996. The page is in the EPA’s web archive.

US EPA. 2015, September 4. Summary of the Food Quality Protection Act. https://www.epa.gov/laws-regulations/summary-food-quality-protection-act.

This web page summarizes the FQPA. It also includes a link to download a PDF of the FQPA, as well as links to more information on registering reduced risk pesticides, minor use pesticides, public health pest designation, registration of antimicrobial pesticides, endocrine disruptor screening, and registration review of pesticides.

US EPA. 2016, February 22. Implementation of Requirements under FQPA. https://archive.epa.gov/pesticides/regulating/laws/fqpa/web/html/fqpa_implementation.html.

This web page explains how the FQPA was implemented by the EPA. It highlights some of the main provisions in the law. The page includes information on improved health standards for food communities, reduced risk pesticides, minor uses, public health pesticides, antimicrobial reform, endocrine disruption, registration review, fee collection, USDA initiatives, integrated pest management, harmonizing standards and requirements, consumer right-to-know, and performance reports.

The Homestead Acts

History.com Editors. 2019, September 3. Homestead Act. https://www.history.com/topics/american-civil-war/homestead-act.

This web page from the History Channel highlights important information about the 1862 Homestead Act, including why the Homestead Act was passed, how people applied for a homestead, how speculators took advantage of the Homestead Act, and the act’s end and repeal. The Homestead Act was signed into law by President Lincoln in 1862. It allowed people to apply for a homestead, and if they met certain requirements, they could take ownership of the land. There were people who took advantage of the act, as outlined on this web page. The act was repealed with the passage of the Federal Land Policy and Management Act of 1976.

National Archives and Records Administration, Office of the Federal Register. 4/1/1985-. 1862. Act of May 20, 1862 (Homestead Act). Statute 392 4. https://catalog.archives.gov/id/299815.

This web page from the National Archives Catalog displays a scanned copy of each of the four original pages of the Act of May 20, 1862, more commonly known as the Homestead Act of 1862. The documents are handwritten and somewhat difficult to read. No transcript is provided on this web page.

NPS. 2019a, September 19. Homesteading Significance. https://www.nps.gov/home/learn/historyculture/homesteading-significance.htm.

This web page from the National Park Service Homestead National Monument of America website concisely describes the importance of the Homestead Act. It goes into further detail on its importance to Nebraska; this monument is in southeast Nebraska in the city of Beatrice.

NPS. 2019b, September 20. About the Homestead Act. https://www.nps.gov/home/learn/historyculture/abouthomesteadactlaw.htm.

This web page from the Homestead National Monument of America describes the history, impact, and effectiveness of the Homestead Act of 1862. The page also highlights the creation of the Homestead National Monument, a monument that commemorates the early pioneers who used the Homestead Act to acquire land and what they encountered while homesteading.

NPS. 2019c, September 20. Homesteading by the Numbers. https://www.nps.gov/home/learn/historyculture/bynumbers.htm.

This web page from the Homestead National Monument of America highlights facts about homesteading, the Homestead Act of 1862, and the Homestead National Monument of America. It also includes links to PDFs that break down homesteading statistics by state.

OurDocuments.gov. 2019. Homestead Act (1862). https://www.ourdocuments.gov/doc.php?flash=false&doc=31.

This web page from OurDocuments.gov highlights the importance of the Homestead Act of 1862 and includes a transcript of the law.

The Superfund Amendments and Reauthorization Act



Fadrowski Drum Disposal EPA Superfund site in Franklin, Wisconsin. Photograph by Markzvo.

US EPA. 2014, July 11. Superfund. https://www.epa.gov/superfund.

This web page for the Superfund program of the EPA provides links to information about Superfund, Superfund task force, community involvement, accomplishments and benefits, cleaning up sites, clean up support, additional resources, contaminants, and contaminated media.

US EPA. 2015, September 9. The Superfund Amendments and Reauthorization Act (SARA). https://www.epa.gov/superfund/superfund-amendments-and-reauthorization-act-sara.

This EPA web page provides an overview of the Superfund Amendments and Reauthorization Act, passed in 1986 to amend the Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

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CHAPTER OVERVIEW

4: Careers

4.1: Careers in Soil and Water Conservation

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4.1: Careers in Soil and Water Conservation

Abbreviations

AAG – American Association of Geographers
AGI – American Geosciences Institute
AGU – American Geophysical Union
AIH – American Institute of Hydrology
ASA – American Society of Agronomy
ASABE – American Society of Agricultural and Biological Engineers
CESSWI – Certified Erosion, Sediment and Stormwater Inspector
CF – Certified Forester
CMS – Clay Minerals Society
CPAg – Certified Professional Agronomist
CPESC – Certified Professional in Erosion and Sediment ControlCPISM – Certified Professional in Stormwater Management
CPMSM – Certified Professional in Municipal Stormwater Management
CPRM – Certified Professional in Rangeland Management
CPSC – Certified Professional Soil Classifier
CPSS – Certified Professional Soil Scientist
CPSWQ – Certified Professional in Stormwater Quality
CSSA – Crop Science Society of AmericaEPA – US Environmental Protection Agency
ESA – Ecological Society of America
GS – General Schedule
GSA – Geological Society of America
NACD – National Association of Conservation Districts
NACTA – North American Colleges and Teachers of Agriculture.
NRCS – Natural Resources Conservation Society
NSPE – National Society of Professional Engineers
PDF – Portable Document Format
PE – Professional Engineer
PG – Professional Geologist
PH – Professional Hydrologist
PWS – Professional Wetland Scientist
SAF – Society of American Foresters
SASES – Students in Agronomy, Soils, and Environmental Science
SRM – Society for Range Management
SSSA – Soil Science Society of America
SWCS – Soil and Water Conservation Society
SWS – Society of Wetland Scientists
URL – Uniform Resource Locator
US – United States
USACE – US Army Corps of Engineers
USDA – US Department of Agriculture



USDA NRCS District Conservationist discussing wetlands conservation practices with landowner who farms near Iowa City, IA.

AgCareers.com. 2019. Career Profiles. https://www.agcareers.com/career-profiles/.

The AgCareers website provides information on a number of different careers in agriculture, including jobs that can be pursued by soil scientists. Information includes the type of educational background required to pursue the given career (both high school preparation and college training), kinds of jobs, and job market outlook.

ASA CSSA SSSA. 2019. Colleges and Universities. https://www.careerplacement.org/colleges.

This page from the ASA, CSSA, and SSSA provides a partial list of universities that provide training in agronomy, crop science, soil science, and environmental science. It is a particularly good resource for high school students looking for degree programs in one of these areas.

ASA CSSA SSSA. 2019. Science Societies Career Center. https://www.careerplacement.org/.

This Career Center website is a job listing website focused on job seekers and recruiters in agronomy, crop science, and soil science disciplines. It allows job seekers to post resumes, which can then be reviewed by recruiters and potential employers. It also lists active job openings that can be reviewed by applicants.

EnvironmentalScience.org. 2019. Careers in Environmental Science. https://www.environmentalscience.org/careers.

The Careers in Environmental Science website gives information on what environmental scientists do, where they can find employment, expected salary levels from different employers, the future job outlook, and where to get relevant education. While soil science is not specifically mentioned as an environmental science preparatory degree, the website gives several examples of places where soil science knowledge is important to the environmental field.

SSSA. 2019. A Day in the Life. https://www.soils.org/careers/a-day-in-the-life.

This SSSA web page features career profiles of professionals in the soil science discipline. It includes career profiles of 25 soil scientists. Each profile begins with a summary of each soil scientist's career, followed by a question-and-answer interview between the SSSA and the profiled soil scientist.

SWCS. 2019. Student and Early Career Resources. https://www.swcs.org/resources/conservation-career-profiles/.

This web page from the SWCS provides students and early career professionals two resources to help plan a career in conservation. First, it contains a link at the top of the page for a 23 page *SWCS Guide for Students and Early Career Professionals in Conservation* as a PDF. In addition, it contains career profiles of conservationists in various types of careers in the discipline.

SWCS. 2019. SWCS Conservation Career Center. https://swcs.careerwebsite.com?site_id=22892.

This Conservation Career Center website from the SWCS provides a platform for job seekers and recruiters for the soil and water conservation profession. Using an account as either a job seeker or a recruiter, people can review or post positions for openings in soil and water conservation. There is also a feature for a free resume review to improve the quality of user resumes.

US Office of Personnel Management. 2019. General Natural Resources Management and Biological Sciences. https://www.usajobs.gov/Search/ExploreOpportunities/?Series=0401.

USAJOBS.gov lists open positions in federal agencies like the USDA NRCS, EPA, USACE, and more. Users create a profile with different resume documents and then may apply for a range of jobs. This web page within USAJobs.gov lists all jobs related to natural resources management and biological sciences related to plant and animal life.

USDA NRCS. 2019. Plan Your Career. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/careers/plan/.

Important information on careers with the USDA NRCS is provided. Specific information is provided for positions as a Soil Conservationist and Soil Scientist, including job functions for each position, qualifications for each level, and typical career paths. The GS grades for each position are also given, which allows prospective employees to look up information on pay rates.

Professional Societies

AAG. 2019. American Association of Geographers. http://www.aag.org/.

The AAG brings together professionals in all aspects of geography, spanning the cultural and physical sides of the field. This includes geographers who work on soil issues. AAG provides networking opportunities, meetings, publications, and works to form bridges with related fields.

AGI. 2019. American Geosciences Institute. https://www.americangeosciences.org/.

The AGI is a network of professional associations that represent geoscientists of all types. Member societies include several that have soil scientists in their membership, including the AAG, AGU, AIH, CMS, GSA, and SSSA.

AGU. 2019. American Geophysical Union. https://www.agu.org/.

The AGU represents scientists that study any aspect of the Earth and space sciences, ranging from astronomers to atmospheric scientists to soil scientists.

AIH. 2019. American Institute of Hydrology – The Society for Certification of Hydrology Professionals. https://www.aihydrology.org/.

The AIH offers professional certification to individuals with a background in any scientific or engineering field who seek to work as hydrologists. This certification ensures that unqualified individuals do not work on the many water projects that are important in our modern society.

ASA. 2019. American Society of Agronomy. https://www.agronomy.org/.

The ASA focuses on the production of crops and turfgrass, including all related areas. Because of the importance of soil in such production, many soil scientists are members of ASA, and the ASA has a special working relationship with the SSSA.

ASA. 2019. SASES: Students of Agronomy, Soils, and Environmental Sciences. https://www.agronomy.org/undergrads.

Undergraduate student members of the ASA, CSSA, and SSSA are members of SASES. Students are affiliated with agronomy, crops, soils, plant science, or environmental science clubs around North America.



The K-State Soil Judging Team evaluates a soil profile in San Luis Obispo, California during the 2019 National Collegiate Soil Judging Competition. This soil judging competition is organized by SASES. Photograph by Colby Moorberg.

ASABE. 2019. ASABE – American Society of Agricultural and Biological Engineers. https://www.asabe.org/.

The ASABE works to advance engineering in agricultural, biological, and food systems. Membership is open to both engineers and non-engineers who have an interest in the society's mission. Benefits to members include national and sectional meetings, publications, and established standards.

CMS. 2019. Clay Minerals Society. http://www.clays.org/.

The CMS focuses on the study of clays and clay minerals. Given the importance of these fine materials in soil, many soil scientists are members of CMS and contribute to their meetings and publications.

CSSA. 2019. Crop Science Society of America. https://www.crops.org/.

The CSSA applies plant science to improve the world we live in. Because of the importance of soil to plant production, many soil scientists are members of CSSA, and CSSA has a special working relationship with the SSSA.

ESA. 2019. Ecological Society of America. https://www.esa.org/.

The ESA seeks to promote ecological science among scientists, increase public awareness of ecological science, increase the resources available to ecological scientists, and ensure the proper use of ecological science in decision making. Benefits to members include meetings, networking, and publications.

GSA. 2019. Geological Society of America. http://www.geosociety.org/.

The GSA represents more than 20,000 geoscientists in countries around the world. They are interested in all aspects of the geosciences and include a Soils and Soil Processes division. GSA serves their members with meetings, publications, and research grants and works to raise public awareness of the geosciences.

NACD. 2019. National Association of Conservation Districts. http://www.nacdnet.org/.

The NACD represents the 3,000 conservation districts in the US along with the people who serve on their governing boards. NACD encourages responsible use of natural resources through established relationships with governmental and non-governmental agencies and industry, educational programs, and publications.

NACTA. 2019. NACTA – North American Colleges and Teachers of Agriculture. https://nactateachers.org/.

The NACTA focuses on providing quality postsecondary education in agriculture and related areas by providing forums to discuss all aspects of such education, including a journal.

NSPE. 2019. National Society of Professional Engineers. https://www.nspe.org/.

The NSPE brings together PEs from all engineering disciplines to discuss issues important to engineers. This includes monitoring legislation that may affect engineers, providing continuing education required to retain PE status, and establishing a code of ethics that engineers must adhere to.

SAF. 2019. Society of American Foresters. https://www.eforester.org/.

The SAF encourages making forest management decisions based on sound science, balancing the needs of modern society with sustainability of forest resources. SAF also seeks to enhance the abilities of its members through meetings, networking, education, and certification.

SRM. 2019. Society for Range Management. http://rangelands.org/.

The SRM is dedicated to studying rangelands, so they can be conserved and managed sustainably through meetings, publications, and other resources made available to members.

SSSA. 2019. Soil Science Society of America. https://www.soils.org/.

The SSSA is the largest professional organization in the US devoted to professional soil scientists and is one of the largest such organizations in the world. SSSA offers services to soil scientists including networking, publication, professional development, and professional certifications.

SWCS. 2019. Soil and Water Conservation Society. https://www.swcs.org/.

The SWCS is dedicated to conserving our natural resources. SWCS has chapters in all 50 states as well as Canada, Mexico, and US Territories. It serves members with conferences, publications, engagement in policy discussions, research projects, and professional development.

SWS. 2019. Society of Wetland Scientists, an International Organization. http://www.sws.org/.

The SWS encourages understanding, conserving, protecting, restoring, and using science-based management of wetlands to promote sustainability through meetings, publications, public outreach, and professional certification.

Professional Credentials

AIH. 2019. Hydrology Certification. https://www.aihydrology.org/hydrology-certification.

This web page from the AIH includes information on the education and experience needed for the PH certification. It also explains examination requirements and fees and links to relevant documents and forms.

ASA. 2019. Certifications. https://www.agronomy.org/certifications.

Information is provided on several certifications offered by the ASA, including the CCA and the CPAg credentials.

EnviroCert International, Inc. 2019a. CESSWI – Certified Erosion, Sediment and Stormwater Inspector. https://www.envirocertintl.org/cesswi/.

Information on becoming a CESSI, including the career benefits of becoming a CESSI and proficiencies that a CESSI must demonstrate.

Envirocert International, Inc. 2019. CPESC – Certified Professional in Erosion & Sediment Control. https://www.envirocertintl.org/cpesc/.

Information is provided on becoming a CPESC, including the career benefits of becoming a CPESC and proficiencies that a CPESC must demonstrate.

EnviroCert International, Inc. 2019b. CPISM – Certified Professional in Stormwater Management. https://www.envirocertintl.org/cpism/.

This web page provides information on becoming a CPISM, including the career benefits of becoming a CPISM and proficiencies that a CPISM must demonstrate.

EnviroCert International, Inc. 2019c. CPMSM – Certified Professional in Municipal Stormwater Management. https://www.envirocertintl.org/cpmsm/.

This web page explains how to become a CPMSM and includes the career benefits of becoming a CPMSM and the proficiencies a CPMSM must demonstrate.

EnviroCert International, Inc. 2019d. CPSWQ – Certified Professional in Stormwater Quality. https://www.envirocertintl.org/cpswq/.

The procedure for becoming a CPSWQ is explained, career benefits of becoming a CPSWQ are included, and the proficiencies a CPSWQ must demonstrate are provided.

EnviroCert International, Inc. 2019e. Envirocert International, Inc. https://www.envirocertintl.org/.

General information is provided on the certifications provided by EnviroCert International, Inc., and how they can advance professional careers. Information is also given on the EnviroCert International, Inc.



Collection of soil pore water from a pressure/vacuum sampler on the corner of a wheat field near Huron, California. Photograph by Philip Melcher, Provost & Pritchard Consulting Group.

NSPE. 2019. What is a PE? https://www.nspe.org/resources/licensure/what-pe.

This page explains what a PE is, the process of becoming a PE, and why being a PE is important. Information is also provided on PE licensure programs.

SAF. 2019. Professional Development. https://www.eforester.org/Main/Certification_Education/Certified_Forester/Main/Certification/Certification_Home.aspx.

Information is provided on becoming a CF, including required educational background, the CF application, reasons to hire a CF, and a directory to find a CF if you need one. Information is also included on CF continuing education requirements and on states that have forestry licensure.

SRM. 2019. Certified Professional in Rangeland Management (CPRM) Committee. http://rangelands.org/committees/cprm-committee/.

The process for becoming a CPRM is explained. Education, experience, and examination requirements are provided along with continuing education requirements to retain certification.

SSSA. 2019. Certifications. https://www.soils.org/certifications.

Information on certifications specific to soil science, including the CPSS and CPSC credentials. This includes education and testing requirements for certification, benefits of certification, and information on who should be certified. A searchable directory of certified soil scientists is also provided.

SWS. 2019. Society of Wetland Scientists Professional Certification. http://www.wetlandcert.org/.

This website provides an explanation of the PWS certification program offered by the Society of Wetland Scientists. Certification requires that applicants meet certain educational and experience requirements. Certification must be renewed every five years by completing appropriate continuing education.

SSSA. 2019. State Soil Science Licensing and Legislation. https://www.soils.org/certifications/already-certified/licensing.

This web page from the SSSA lists contact information for the governing boards for states with soil science licensure programs. The nine states listed each require practicing soil scientists to be licensed by the state.

Tepel, R. E. 2012. What Geology Students Need to Know About Professional Licensure. American Institute of Professional Geologists. http://www.aipg.org/Students/studenttopics/What%20geology%20students%20need%20to%20know%20about%20professional%20licensure.pdf.

This article from the American Institute of Professional Geologists explains why licensure is important and what types of licensure fall into the scope of work for PG. There are tips for taking the licensure examination and information on classes that help in preparing for the examination. The URL offers a direct download of a PDF of this resource.

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Glossary

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