

Exploring Tilling vs. No-Till Gardening

Overview: Beginning each planting season by tilling the soil was once considered a garden and agricultural essential, but research — and history — indicate the environmental costs may outweigh the benefits realized. In this lesson, students will explore the resurgence of no-till growing and discover why it is important to continually observe, gather data, evaluate, and reflect on the impacts of human interactions on nature and ecosystem health.



Grade Level/Range: 9-12th

Objective(s): Students will:

- Research the history of the practice of tilling the soil.
- Explore arguments for and against tilling and create a list of its costs and benefits.
- Design and conduct experiments to demonstrate the impact of tilling on soil structure.
- Discuss why it is essential to continually monitor the impact of human activity on the environment.

Time: 2+ hours

Materials:

- Internet access
- Trowels
- Buckets
- Soil samples
- Magnifying glasses
- Water
- Supplies for student-designed experiments (such as soil, plastic containers, and fine netting)

Background Information:

Since the dawn of agriculture, humans have used implements to loosen soil and remove competing plants ("weeds") to give their crop plants the best chance to grow. Tilling is a term that refers to the practice of digging, stirring, turning over, and other mechanical means of preparing soil for planting.

Any time you disturb the soil, you affect its delicate ecosystem and the organisms that reside there. Some organisms are killed directly; others may be harmed through exposure to drying air or sunlight. In addition, the act of tilling breaks up the soil aggregates — groupings of soil particles held together with humus and other organic compounds. These aggregates are vital to soil *and* plant health because they reduce compaction and create pore spaces that allow water and air to move through the soil. More on that later.

The invention of the plow to till the soil was seen as a technological breakthrough. Initially pulled by horses, plows dug deeper into the soil and turned over larger masses of soil than earlier implements, decreasing the time it took farmers to plant their crops. University of Minnesota Extension offers a brief [history of tillage and tillage research](#).

The Dust Bowl era in the United States during the 1930s was an early sign that widespread and frequent plowing and tilling had negative environmental impacts. Before the spread of homesteads and farming in the nineteenth century, much of the American Great Plains region was home to prairies of native grasses fed on by herds of grazing animals. The deep and extensive fibrous roots of the native grasses provided a sturdy network that anchored the soil in place when strong winds blew,

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and the animals' manure provided a constant source of organic matter to return lost nutrients to the soil. Thus, these native grasses were very resilient during times of drought.

As farmers moved in, they fenced in (or out) the animals and plowed the fields to remove the native grasses and create areas of bare, flat soil. In the short term, this made planting, growing, and harvesting faster and easier for farmers. However, the practice has its downsides.

- Tilling damages soil structure by breaking up soil aggregates, resulting in powder-like soil particles at the surface that are vulnerable to compaction and erosion by wind and rain.
- Breaking apart the soil aggregates results in the loss of the network of pore space beneath the surface that allows water and air to move through the soil. This can damage plants whose roots need water and air to survive.
- Tilling also impacts many soil organisms that rely on water, air, and plant life for survival.
- Repeated tilling and plowing can create a hardpan layer beneath the loosened soil that is impervious to water.

At first, the existing soil of the Great Plains retained some of its structure and fertility. However, repeated tilling and harvesting of field crops ("The Great Plow-Up") and the absence of animal manure soon destroyed the soil's structure and fertility. The situation reached crisis level when a drought hit in the 1930s.

Unlike the native prairie plants, which were adapted to occasional droughts, the farmers' field crops withered and died. Now powdery and dry, the bare soil lacked the strong network of native grass roots to anchor it in place, and the plains' strong, relentless winds picked up the topsoil and carried it away in massive dust storms. The catastrophic loss of topsoil quickly led to widespread hunger and poverty. The Dust Bowl is a prime example of human actions impacting earth systems, including climate, in a significant way.

Soil Structure and Pore Space - Soil structure describes the way individual particles of soil (clay, silt, and sand) are loosely adhered in small clumps called aggregates. These aggregates are formed through physical, chemical, and biological activity in the soil in a complex interplay of mineral particles, organic matter, microbes, and fungi.

Due to their larger size, these aggregates create more space around one another in the soil than tiny, unaggregated soil particles (think sand vs. marbles in a jar). This space between the aggregates is called pore space, and it is a critical component of healthy soils that can support plant life. In general, plants grow best when about 50 percent of the volume of the soil is pore space, with half of that filled with water and half filled with air. The other 50 percent of the soil is made up of inorganic particles (clay, silt, and sand) and organic matter.

Some soils are naturally low in pore space. For example, clay particles are very small and flat and will stick together when wet. If soil contains a lot of clay, it will likely be low in pore space and drain poorly. However, pore space can also be impacted by human treatment of the soil:

- Heavy plows and other machinery can compress the soil, leading to the loss of pore space.
- Pore space will collapse in tilled soil (especially when wet).
- Removal of plant matter, such as when fields are cleared for planting, also means a decrease in the decomposition and biological activity in the soil that help create the pore space.
- Soil left bare is subject to compaction and loss of pore space due to weather, such as pounding rain.

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Gardeners and farmers are rediscovering ways to garden without tilling — methods that many indigenous peoples have used for thousands of years and continue to use today. The technique of no-till gardening (also sometimes called no-dig gardening) entails a variety of methods, including keeping the soil covered with compost and mulch to prevent weed growth and soil erosion. On a large scale, farmers are also embracing new no-till practices by avoiding disruption of the soil, keeping the soil continuously covered, and planting through crop residues and cover crops.

Laying the Groundwork:

Ask students to read an article about no-till gardening or farming. Here are a few articles to consider:

- [Reduced Soil Tilling Helps Both Soils and Yields](#) by Michelle Horton. Stanford Woods Institute for the Environment, Stanford University. December 7, 2019.
- [Did John Deere's Best Invention Spark a Revolution or an Environmental Disaster?](#) by Jackson Landers. Smithsonian Magazine. December 17, 2015
- [No-Till: The Quiet Revolution](#) by David R. Huggins and John P. Reganold. Scientific American. July 2008 pp. 70-77.

From their reading, ask them to make a list of the costs and benefits associated with tilling and no-till gardening when farming.

To further dive into the topic, students may also find videos about [The Dust Bowl](#) by Ken Burns on PBS, an interesting way to dig into the topic of tilling soil.

Exploration:

1. Bring in an assortment of soil samples or ask students to bring in soil samples (make sure to have them note where they obtained the samples and ask permission as needed before collecting).
2. Ask students to compare the different samples, noting color, presence of roots, and other features. Next, have students use a magnifying glass to inspect the samples and note the similarities and differences they observe in soil structure. Are the soil particles held together in aggregates? Are the aggregates in some soils larger than in others?
3. Watch a video about the [Slake and Infiltration Test by Ray Archuleta](#) comparing soil that has been tilled versus soil that has not been subject to tilling.
4. Using this demonstration as inspiration, ask students to devise their own experiments to test the properties of the soil samples you have collected. For example, they might design an experiment to compare soil drainage or susceptibility to wind erosion.
5. Ask them to compile their results and discuss their findings. Did their experiments support the research they completed on tilled vs. no-till soil? Why or why not? Would they make any changes to their experimental methods?

Making Connections:

Ask students to team up to create a presentation or brochure to share with community members about the benefits and best practices of no-till gardening. Find a way to share it in person or electronically.

As a class, discuss the initial adoption of tilling/plowing and the motivation of gardeners and farmers to use this practice. Which did people note first – the benefits of the practice or the negative impacts? Do you think they ignored the negative impacts or just did not see them? Do you think they could have/should have anticipated the negative impacts on the environment? What does this teach us about looking at the

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ecosystem as a connected whole? What lessons should humans learn from this evolution of technological advances?

Branching Out:

Disturbing the soil through processes such as tilling has an impact beyond soil structure and soil air/water capacity — it also results in the release of carbon into the atmosphere. Follow up with the lesson [The Soil-Air Connection: A Carbon Cycle Lesson](#) for students to learn more about ways tilling of the soil impacts climate change.

History is full of examples where technological benefits designed to improve the lives of humans ended up having a negative impact on other elements of our ecosystems. Branch out beyond the soil and explore how man-made pesticides and synthetic fertilizers have also impacted the environment. The book *Silent Spring* by Rachel Carson is a classic read to dive deeper into this topic.

Related KidsGardening Articles:

- [All the Dirt on Soil](#)
- [Preparing the Soil](#)
- [Seven Ways to Nurture Healthy Soil in the Fall](#)
- [Soil Texture and Composition](#)
- [The Plant Soil Relationship](#)
- [Soil is Alive](#)
- [The Soil Air: A Carbon Cycle Lesson](#)

Related KidsGardening Webinars:

- [No-Dig Gardening For Kids' Garden Success](#)
- [Ecological Gardening: Companion Planting and Other Earth-Friendly Practices](#)

Related NGSS Disciplinary Core Ideas and Performance Expectations:

HS-ESS2 Earth's Systems

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling

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biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth’s systems and life on Earth. [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth’s other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth’s surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth’s other systems.]

HS-ESS3 Earth and Human Activity

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

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