TractorCraft: SECRETS OF SOIL

DOCUMENT PURPOSE

This document is to serve as a companion study guide to provide additional educational content in support of TractorCraft: Secrets of the Soil as an agricultural STEM platform in Minecraft Education.

TractorCraft: Secrets of Soil teaches students about soil health as a key factor in how agricultural or farm fields adapt to change and maintain a healthy system through management practices that improve how soil, water, plants, animals, and humans interact together.

KEY CONCEPTS

- Soil health and the foundational role of soil carbon in healthy systems.
- Regenerative agriculture and climate-smart agriculture – role of carbon and soil health.
- Ecosystem services concepts – contribution of land to delivering on societal needs.
- Food equity – principle of all people having the ability and opportunity to grow and consume healthy and affordable foods also that meet cultural needs.

KEY TERMS & DEFINITIONS

- Carbon – a chemical element that is the building block of life; found in the air as carbon dioxide and in the soil as organic matter; can be a source of nutrients; helps soil structure; can increase microbial activity; can increase water availability.
- Climate-smart agriculture – an overall management approach guided by positive climate outcomes in agriculture.
- Ecosystem services – the benefits and transfer of benefits that a natural environment provides to society.
- Regenerative agriculture – a conservation approach to agricultural production focused on adaptation to change.
- Soil health – the degree of positive interactions between elements in the soil system with focus on a soil's ability to perform resiliently.
- Sustainable – meeting present needs without compromising future needs.

CONCEPTS – PROGRESSION AND LINKAGES

1. Soil health is a fundamental building block of healthy and regenerative agricultural systems – it addresses the adage of 'manage the roots, sell the shoots' noting that managing the soil properly will provide a good foundation for plant production.
2. Healthy soils have potential to sequester and store carbon while also creating a strong production platform for producing crops.
3. Healthy agricultural lands provide ecosystem services in serving core societal needs.
4. Healthy and productive land contributes to core societal needs through the potential for growing and providing food in an equitable manner across a diverse range of needs.

LEARNING OBJECTIVES

Students will gain knowledge, skills, and experience to accomplish the following.

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- Understand the basics of soil health while building upon the principles of crop production outlined in the original TractorCraft world in Minecraft Education.
- Learn how healthy soils can store water and carbon while building upon the principles of soil management outlined in the original TractorCraft.
- Understand how healthy agricultural systems (incorporating a broader understanding of the interactions between weather, climate, soil, and water) can contribute to equitable food systems in serving core societal needs.

GUIDING IDEAS

- Basic physical science – the role of soil plays in regenerative and sustainable food production.
- Applied physical science – agricultural management steps needed to support such systems.
- Social science – the role of a healthy soil in serving core societal needs while addressing climate change, providing for food equity, and fostering sustainable systems.

PERFORMANCE EXPECTATIONS

- Students can demonstrate knowledge of soil management contributing to soil health throughout and across crop production cycles including soil preparation, crop planting, crop protection and crop harvesting.
- Students understand the role of interconnected management decisions in impacting healthy soil systems.
- Students understand the importance of a healthy soil in building regenerative and adaptable agricultural systems that generate important societal outcomes.
- All performance expectations to build upon the original TractorCraft study guide.

LEARNING DETAILS

- Explore climate-smart agriculture approaches – increased productivity, enhanced resiliency, and reduced emissions.
- Explore minimized soil disturbances in crop production systems using limited or no-till tillage practices – minimize physical, biological, and natural materials and promote nutrient cycling.
- Explore soil coverage through reduced tillage and use of continuous vegetation and natural materials – e.g., cover crops, and pastures with minimization of weed growth, pest reduction, and reduction of added fertilizer.
- Explore methods to increase plant diversity by build healthy soils to retain excess water and nutrients while growing biodiversity and providing benefits to wildlife and pollinators.
- Explore the production of soil health by building organic matter and living roots in the soil while maintaining soil coverage – e.g., plant winter crops, maintain land in permanent pasture while stabilizing the soil, retaining excess water and reducing nutrient runoff.
- Explore how regenerative agriculture aids food security and food equity.

UN SUSTAINABLE DEVELOPMENT GOALS (SDG) ALIGNMENT

2. Zero Hunger
3. Good Health and Well-Being
10. Reduced Inequalities
12. Responsible Consumption and Production

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13. Climate Action
15. Life on Land

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LESSON 1 – BIOGEOCHEMICAL CYCLES

Primary Learning Points

1. Definition of biogeochemical cycles – inclusive of biology, geology, and chemistry.
2. High level concept of elements (e.g., water, carbon, nitrogen, oxygen, others) that cycle through sources and sinks as natural pathways to support life.
3. Basic factors that can affect the biogeochemical cycles.

Biogeochemical cycles are fundamental to life in that they describe natural processes that involve the interaction of biology (i.e., bio), geology (i.e., geo), and chemistry (i.e., chemical). They are the natural pathways by which essential elements of living matter are circulated. They consist of living and nonliving components.

In a natural environment (e.g., farm field), plants, microorganisms and animals that live and die makeup the biology. The earth is the physical geological environment in which plants and animals live and die / decompose. The process by which the living or organic matter (i.e., plants, animals) returns to the chemical elements in the earth is the chemical process.

For living elements in an ecosystem to survive, the common chemical elements (water, carbon, nitrogen, oxygen, phosphorus, hydrogen, sulfur) that make up the living organisms must cycle continuously. Each of these chemical elements has a biogeochemical cycle that has a source and a sink whereby the source is something that releases an element (e.g., carbon, nitrogen, oxygen), and a sink that stores an element.

Weather, climate, and human activity affect biogeochemical cycles. These cycles are important parts of an agricultural production system relative to the different elements needed to produce crops in a sustainable manner by meeting societal needs for food, feed, fiber, and fuel while not impacting the environment negatively relative to the production practices used.

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LESSON 2 – CARBON CYCLE

Primary Learning Points

1. Definition of carbon.
2. Carbon cycling with the concept of sources and sinks.
3. Connection of carbon to agricultural soils and related production.

Carbon is a chemical element that is the foundation of life. All living things contain carbon. It is found in our atmosphere as carbon dioxide and helps regulate the earth's temperature. It serves as a key ingredient in our food and a key element in many energy sources.

Carbon is an element that is cycled continuously. The carbon cycle is the natural movement and exchange of recycling and reusing carbon atoms traveling from the atmosphere into organisms on the earth while then moving back into the atmosphere continuously. Most carbon is stored in soil, rocks, and sediment while the ocean, atmosphere, and living organisms also store carbon. All are examples of sinks. Carbon can be released and cycled when organisms die, fires burn, and/or when humans burn fossil fuels. All are examples of sources.

As an example of cycling from sources to sinks, humans and animals exhale carbon as carbon dioxide while plants intake carbon dioxide to produce and release oxygen. The amount of carbon on our planet and in our atmosphere is fixed and does not change. The relative proportion of carbon that is stored versus released changes. In an agricultural system, stored carbon in the soil can create healthier soils capable of sustaining higher agricultural production while releasing carbon into the atmosphere can foster climate change with less capacity to regulate warmer temperatures.

Along with the water cycle and nitrogen cycle, the carbon cycle is a key process to sustain life on earth. Water, nitrogen, oxygen, phosphorus, and carbon cycles are key factors in agricultural production.

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LESSON 3 – SOIL HEALTH – OVERVIEW

Primary Learning Points

1. Definition of soil health.
2. Concept of soil as a fundamental to agriculture.
3. Overview of soil health indicators and measures.

Soil health refers to the degree of positive interactions between elements in the soil system with focus on a soil's ability to perform resiliently. It is the capacity of soil to function as a vital living system to sustain productivity, maintain environmental quality, and promote life. Soil is the foundation of agricultural production in that it contains living organisms that perform functions required to produce food, feed, fiber, and fuel to meet societal needs. As a living system, soil is a dynamic system that contains microorganisms, bacteria, and fungi.

Carbon is a key building block of soil. As a living system and foundation for agriculture, soil cycles nutrients (e.g., nitrogen, carbon, phosphorus, others) needed for plant growth, sustains plant and animal life by cycling nutrients and supporting biodiversity, filters, and buffers pollutants, regulates water, and provides a stable physical environment to support plant growth and life.

At the most basic level, soil health is defined by color, structure, presence of biological activity, rooting resistance, and smell. A healthy soil is dark and porous as a home to organisms including worms. It provides a balanced amount of air, water, and organic matter for plants and microorganisms to grow.

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LESSON 4 – SOIL HEALTH – PRINCIPLES

Primary Learning Points

1. Principles of soil health.
2. Concept of how soil management impacts soil health with resulting effects on agricultural production, climate change, and other factors.

The core principles of soil health generally are accepted as managing soil cover, minimizing soil disturbance, maintaining plant diversity, and increasing biodiversity, and maintaining live plants and roots above and below ground. An important additional principle is context whereby practical and influencing factors must be considered in undertaking practices and measures to promote soil health.

Soil has both inherent and dynamic qualities. The primary inherent quality is a soil's ability to function primarily as a medium for life. The dynamic soil quality refers to how a soil changes when managed. Soil management may take the form of adding nutrients, tillage (e.g., conventional tillage, minimum tillage, no-till), grading to improve water flow, use of cover crops, managing residue, or other practices.

A goal for soil management is to improve soil health to increase soil carbon. Generally, this will promote soil structure or tilth. This will improve soil aeration (i.e., oxygen in the soil) and water drainage and retention while reducing the risk of erosion and nutrient leaching. Management choices affect the amount of soil organic matter, soil structure, soil depth, and water and nutrient holding capacity. A key factor in improving soil health is to understand how different soil management interactions impact the soil relative to its inherent properties and the landscape as well as ecosystem. To improve soil health, there is no single approach that works best in all cases.

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LESSON 5 – SOIL HEALTH – AG PRODUCTION

Primary Learning Points

1. Ag production practices have varying levels of effect on soil health.
2. Concept of carbon farming factoring carbon management into agricultural production.
3. Concept of regenerative farming and its relation to carbon farming.
4. Understanding that no single approach will address all issues nor goals as agricultural practices need to be tailored to targeted outcomes.

To achieve agricultural outputs that meet societal needs, soil must be managed actively throughout a growing season. Soil health is a key measure of how well a soil is managed for productivity and sustainability. A central factor in determining soil health is the amount of soil organic matter or soil carbon maintained in the soil throughout the growing season. Soil carbon is influenced by agricultural production and management practices.

One concept with focus in agriculture is carbon farming as a central focus of regenerative agriculture. Carbon farming is an approach to optimizing the storage of carbon in an agricultural production system. It focuses on practices that are known to improve the rate at which carbon is removed from the atmosphere and stored in plant material or as soil organic matter. It is synonymous with the concept of regenerative agriculture as a management philosophy that seeks to improve soil health by restoring degraded soils using ecological principles.

Carbon farming uses management practices known to store carbon and/or reduce greenhouse gas emissions. Such practices increased the water holding capacity of soils, biodiversity, and resilience as well as fertility and productivity. All are targeted to improve soil health and carbon storage. The following are example management practices.

- Cover crop establishment and management and cycling
- Soil tillage – e.g., conventional till, no till, minimum till, strip till
- Residue management as a function of harvest and tillage
- Crop selection and establishment practices
- Water management (surface and subsurface)

Carbon farming can provide several advantages in offsetting carbon emissions, reducing the volume of greenhouse gasses released into the atmosphere, increasing soil fertility, increasing microbial activity and soil biodiversity, minimizing soil erosion and nutrient runoff while maintaining water quality and improving crop yields.

Agricultural production practices can be chosen to manage the soil carbon level in balance with other management considerations. While the preservation and storage of carbon is important, it is not an absolute to drive singular management decisions. All management decisions should be considered in balance of many influencing factors.

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LESSON 6 – SOIL HEALTH – CLIMATE CHANGE

Primary Learning Points

1. Relationship of agricultural production practices to climate change.
2. Basic relationships between agricultural production practices, soil health and climate change with focus on understanding how greenhouse gas emissions and storage can affect climate change.

The goal of agricultural production is to produce what is generally categorized as food, fiber, fuel, and feed. Agricultural production can produce greenhouse gas emissions that can contribute to climate change. Agricultural production also can mitigate the effects of climate change by storing greenhouse gases including carbon. The balance between the contribution (source) and storage (sink) of greenhouse gases in an agricultural system is dependent in part on the choice of management practices.

Sound agricultural management practices will provide the best opportunity to store carbon. Related considerations include how the ground is prepared and managed, as well as how inputs (e.g., fertilizer) are managed, utilized, and sourced. All such management decisions should be made as part of a comprehensive strategy that balances production (e.g., crop yield and quality) with sustainability and resulting factors like carbon storage.

Producers have many options when it comes to management practices. A thoughtful approach to management can position agricultural production as a primary storage (sink) center for greenhouse gasses. Soil health is a key target to achieve carbon storage. The benefits of soil health relative to mitigating climate change include enhanced carbons storage in soils, preservation of existing soil carbon and the reduction of carbon dioxide and other greenhouse gas emissions. Healthy soils also can regulate drainage, water flow, and the storage of compounds (e.g., nutrients) dissolved in water thereby improving water quality. They also can help recharge groundwater and/or water use by plants. Healthy soils also can help support biodiversity and microbial activity in soils which helps breakdown residue and thereby improving carbon storage. Healthy soils also help manage water and aid water quality. Similarly, healthy soils also may help regulate soil temperature.

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LESSON 7 – SOIL HEALTH – FOOD EQUITY

Primary Learning Points

1. Soil health relationship to food equity, food availability, and food security.

Healthy soils are the foundation of sound agricultural production. The management practices (e.g., tillage, conservation, fertility, and others) that a farmer undertakes influence soil health. For example, practices that may store and preserve carbon support soil health.

Healthy agricultural systems provide an opportunity for food equity as a concept that values all people having the ability and means to grow and consume healthy, nutritious, and affordable food consistently. Maintaining an ability to grow and produce food is an equitable societal factor.

In fostering healthy agricultural systems, soil health also supports broader food availability as food that can then be produced in a greater range of areas near urban centers and in traditionally less productive agricultural areas. Greater food availability also provides for reduced waste (e.g., reduced emissions in transport through more locally sourced foods) and loss while also providing for more culturally appropriate foods grown closer to consumption areas. Soil health also supports a foundation for food security by creating opportunities for investment in research and innovation to enhance yields and improve plant health.

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