Cover Crops

Phenomenon/Problem:

How can crops that are not harvested influence the success of the crops that follow?

Cover crops are often planted between growing seasons to help manage soil nutrients, particularly nitrogen. Because nitrogen is essential for plant growth but can be lost from the soil over time, the presence of a cover crop may influence how much nitrogen remains available for future crops.

Essential Questions:

- How do cover crops help reduce nitrogen loss in soil, and what is their impact on soil health and crop yields?
- How do cover crops affect the yield of the following crop, and under what conditions?
- How can a crop that is never harvested affect the success of the crop that follows?
- What happens in a field between harvest and the next growing season?
- How does nitrogen move between soil, plants, water, and other parts of an ecosystem?
- How do living organisms influence the cycling of matter in agricultural systems?
- How do farmers manage ecosystems to support future crop growth?

Stimuli: How will students experience and/or observe the phenomenon/problem?

Cover crops are planted after another crop, such as corn or soybeans, is harvested. Depending on the region, farmers may plant seeds directly into the soil, scatter them across a field, or plant them while the main crop is still standing. Common cover crops include cereal rye, oats, hairy vetch, crimson clover, winter peas, radishes, and multi-species mixes.

Farmers select different cover crop species based on climate, growing conditions, and the goals they have for their fields, such as nutrient management, erosion control, livestock forage, or soil improvement.

Unlike corn or soybeans, cover crops are usually not harvested. Instead, farmers terminate them before planting the next crop. Termination may occur through mowing, rolling (flattening the plants with specialized equipment), winter-kill (when cold temperatures naturally kill the crop), or herbicide application. The plant residue is left in or on the soil, where it eventually decomposes.

Cereal rye cover crop:



Corn growing between a clover cover crop:



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Farmers who use cover crops often report differences in how their fields perform compared to other fields without cover crops between growing seasons. Cover crops are used throughout the United States, although the species selected and the reasons for using them may differ among regions.

The 2022-2023 National Cover Crop Survey, which included responses from 795 farmers across 49 states, found that farmers with 10 or more years of cover crop experience reported average yield increases of approximately 6.27% for corn and 6.30% for soybeans compared to fields without cover crops. Researchers noted that positive yield responses were more common among growers with longer-term experience using cover crops.

Source: 2022-2023 National Cover Crop Survey, conducted by SARE, CTIC, and ASTA

Related Phenomena/Problems:

- Why do some fields require more fertilizer than others to produce similar yields?
- Why can two fields receiving the same amount of fertilizer have different amounts of nitrogen remaining in the soil months later?
- Why are cover crops often planted before nitrogen-demanding crops such as corn?
- Why does soil containing more organic matter often support healthier crop growth?
- Why do many farmers leave plant residue on fields after harvest instead of removing it?
- How is managing the soil fertility in a field similar to a garden? How is it different?

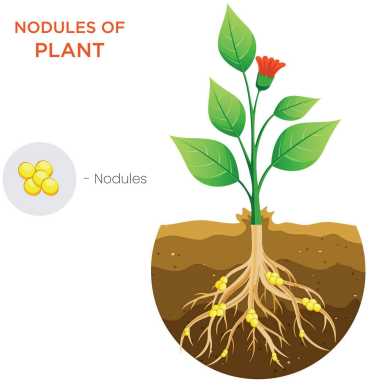
Considerations for Instructional Design:

- Have students analyze yield data from fields with and without cover crops and make an initial claim about why differences in crop performance might occur.
- Engage students in developing and revising models that show what happens in a field between harvest and the next growing season, including the movement of matter through the soil, plants, and surrounding environment.
- Have students ask questions about what happens to nutrients remaining in the soil after harvest and identify what additional evidence would help explain the observed yield differences.
- Provide students with data on cover crop growth, soil nutrient levels, or nitrate movement and have them construct an evidence-based explanation for how cover crops influence future crop growth.
- Engage students in analyzing patterns and identifying cause-and-effect relationships between cover crop use, nitrogen retention, and crop yields.
- Have students compare fields managed with and without cover crops and evaluate how a single management practice can change the movement of matter through an agricultural system.
- Encourage students to develop and use models to trace the path of nitrogen through the agricultural ecosystem, including uptake by plants, storage in plant tissues, decomposition, and return to the soil.
- Have students construct explanations for how cover crops can influence the availability of resources needed for future plant growth.
- Have students analyze data related to cover crop establishment costs, fertilizer inputs, and crop yields and use evidence to construct arguments about the trade-offs associated with different agricultural management decisions.

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Explanation:



Nitrogen

Plants absorb water and dissolved nutrients through their roots. Nitrate (NO_3^-) is dissolved in soil water and can be taken up by roots through specialized transport proteins located in root cell membranes. Once inside the plant, the nitrogen is incorporated into amino acids, proteins, chlorophyll, and other molecules that support growth.

Cover crops continue growing during periods when many agricultural fields would otherwise have little or no active plant growth. Species such as cereal rye often develop extensive root systems that continue absorbing water and nutrients from the soil after harvest. Because these roots remain active during the fall and spring, they can capture nitrate that might otherwise move beyond the reach of future crop roots.

In addition to absorbing nutrients, cover crops help protect the soil surface. Living roots hold soil particles together, while stems and leaves help reduce the impact of rainfall and slow wind movement across the soil. As a result, cover crops can reduce both water erosion and wind erosion, helping keep topsoil in place between growing seasons.

Corn plants require large quantities of nitrogen to build proteins, chlorophyll, enzymes, and DNA. When crops are harvested, not all nitrogen leaves the field with the grain. Depending on weather conditions, fertilizer applications, and crop performance, significant amounts of nitrogen may remain in the soil.

Many forms of nitrogen in soil eventually become nitrate (NO_3^-). Because nitrate dissolves easily in water, it can move downward through the soil profile when rain or snowmelt occurs. If nitrate moves below the root zone, future crops may no longer be able to access it. This is known as nitrate leaching.

Cover Crops and Nitrogen

When a field is planted with a cover crop, living roots continue growing after the main harvested crop (commodity crop) has been harvested. Those roots absorb water and dissolved nutrients from the soil. Nitrogen that might otherwise be transported away becomes incorporated into stems, leaves, and roots. Grasses such as rye act as nitrogen scavengers because they are particularly effective at capturing leftover nitrate from the soil.

Some cover crops, including legumes such as crimson clover and winter peas, also contribute to the nitrogen cycle through nitrogen fixation. These plants form relationships with nitrogen-fixing bacteria that convert atmospheric nitrogen gas into forms that can be used by plants. As a result, different cover crop species can influence soil nitrogen in different ways.

A global meta-analysis found that cover crops reduced nitrate leaching by an average of 56% compared with fields without cover crops. An analysis summarized by SARE found reductions ranging from 1% to 89%, with a median reduction of 48%.

Decomposition

The cover crop is terminated before the commodity crop is planted to initiate decomposition. Decomposers, such as bacteria and fungi, begin breaking down the plant material. As decomposition occurs, nutrients contained within the cover crop are gradually released back into the soil. The nitrogen that had been temporarily stored in roots and shoots can become available again to future crops.

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Viewed this way, the cover crop acts somewhat like a temporary storage system:



- Nitrogen remains in the soil after harvest.
- Cover crop roots absorb that nitrogen.
- Nitrogen becomes stored in plant biomass.
- The cover crop is terminated.
- Decomposition returns nitrogen to the soil.
- The next crop can access that nitrogen.

Cover crops are planted during a period that would typically have few or no actively growing plants. By introducing a living organism into the system, farmers alter the pathways through which matter moves. Because less nitrogen leaves the field and more remains cycling within the ecosystem, future crops may have greater access to the nutrients they need for growth.

Tradeoffs and Production Decisions

Although cover crops can offer benefits, they also come with costs and risks, and farmers weigh these carefully. Seed, planting, and termination all require money, time, labor, and equipment, often during busy seasons. In northern states, the window between fall harvest and winter may be too short for a cover crop to establish well. In drier regions, water is often the deciding factor: a cover crop uses soil moisture that the following crop may need, which helps explain why cover crops are more common in humid regions than in semi-arid ones.

Student and teacher questions about this phenomenon/problem that could be instructionally productive:

- Why would a farmer plant a crop and not harvest it?
- If cover crops are not harvested, what purpose do they serve?
- What is different about the soil in fields with cover crops?
- Are cover crops adding something to the system, preventing something from leaving, or both?
- What evidence would help explain the connection between cover crops and crop yields?

Explaining the phenomenon/problem or related phenomena could lead students toward developing the following DCIs:

HS-LS2.B:
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. Plants or algae form the lowest level of the food web. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

HS-ESS3.C:
- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

HS-LS1.C-H3:
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

HS-LS1.A-H1:
- Systems of specialized cells within organisms help them perform the essential functions of life.

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Notes about relevance and authenticity (funds of knowledge, interests, identity)
Why might students be engaged?

- Connects directly to food production and agricultural systems that affect students' communities, economies, and daily lives.
- Encourages students to investigate a real-world agricultural practice used by farmers across the United States.
- Builds on students' existing ideas about plant growth by challenging them to explain why farmers would intentionally grow a crop that is never harvested.
- Provides an opportunity to explore how human decisions can influence the movement of nutrients through ecosystems and affect future crop growth.
- Connects biology, ecology, environmental science, and agriculture through a phenomenon that has observable impacts on crop yields.
- Allows students with agricultural backgrounds to draw on personal and family experiences while providing authentic entry points for students with limited farming experience.
- Demonstrates how understanding natural cycles, such as the nitrogen cycle, can help explain outcomes in real agricultural systems.

Resources/References

https://www.sare.org/resources/national-cover-crop-survey-reports/

https://ctic.org/national-cover-crop-survey/

https://www.ars.usda.gov/research/publications/publication/?seqNo115=352581

https://www.ers.usda.gov/data-products/charts-of-note/108950

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