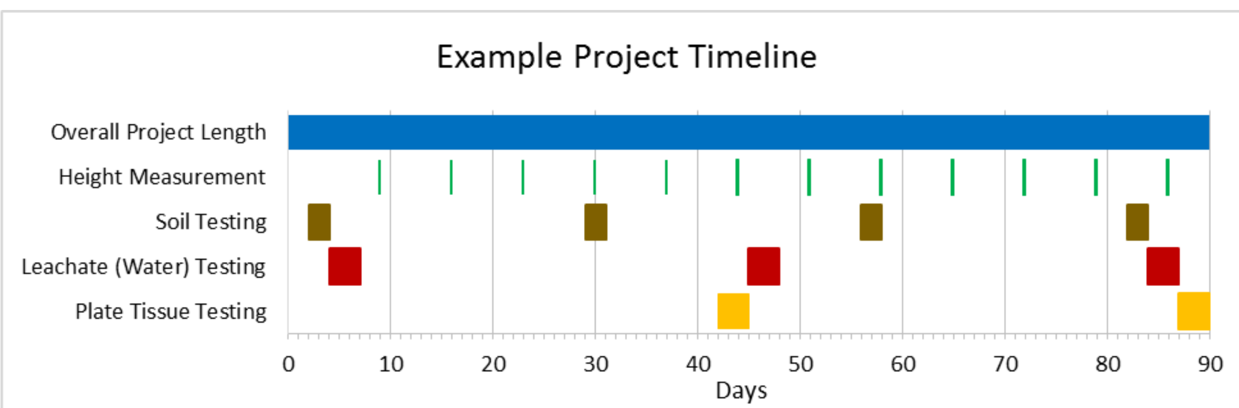
# Nutrient Cycling in Terrestrial Ecosystems
# Biology – 10th Grade

**Unit Summary:** In this unit, students will investigate the role of soil in nutrient cycling and plant growth. Tests will be performed on soil, plant tissue, and soil water. Long-term trends will be tracked, highlighting the dynamic nature of nutrients in terrestrial systems, and reinforcing the concept of matter cycling. Experimental methodologies are student-derived, allowing students the opportunity to design an experiment to address a scientific question. Assessment is based primarily around the creation of lab reports, with emphasis placed on the presentation and analysis of collected data. The unit is designed to fit alongside course material addressing the cycles of other matter (e.g. carbon and water). Students should begin the unit with a basic familiarity with the scientific method and experimental design. Students should also have an understanding of the importance of soil in terrestrial ecosystems, and that matter is constantly cycling between forms.

This unit is designed around a base experiment, presented in Lesson 1 (*Effects of Soil on Plant Growth Rate and Survival*), in which students examine the impact of growing media on plant growth rates. In the lessons that follow, students will conduct additional investigations based upon this initial experiment, in which they seek to examine a potential causal factor for observed differences in growth rate (*Lesson 2: Soil Nutrient Availability and Dynamics*), the relationship between soil nutrient availability and plant nutrient deficiencies (*Lesson 3: Plant Tissue Nutrient Content*), and the relationship between soil nutrient availability and human disturbances that affect nutrient movement (*Lesson 4: Nutrient Losses via Water Movement and Potential Ecosystem Effects*). The effect of soil type on soil water holding capacity is covered in an optional activity in Lesson 2.

Below is a suggested timeline to aid in visualizing how each of these activities fit into the larger experiment. The number of sampling events can be modified to fit the needs of the class or time available.



## Michigan Content Expectations:

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| **B1.1A** | Generate new questions that can be investigated in the laboratory or field. |
| **B1.1B** | Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions. |
| **B1.1C** | Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision). |
| **B1.1D** | Identify patterns in data and relate them to theoretical models. |
| **B1.1E** | Describe a reason for a given conclusion using evidence from an investigation. |
| **B1.1F** | Predict what would happen if the variables, methods, or timing of an investigation were changed. |
| **B1.1H** | Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables. |
| **L2.p1B** | Explain the importance of both water and the element carbon to cells. *(prerequisite)* |
| **B3.3b** | Describe environmental processes (e.g., the carbon and nitrogen cycles) and their role in processing matter crucial for sustaining life. |
| **B3.4A** | Describe ecosystem stability. Understand that if a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages of succession that eventually result in a system similar to the original one. |
| **B3.4C** | Examine the negative impact of human activities. |
| **B3.5e** | Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of population dynamics within ecosystems. |

## Learning Objectives:

1. Students will be able to identify the steps of the scientific method.
2. Students will be able to design a scientific experiment to address a specific question, and critically evaluate the experimental designs of others.
3. Students will be able to analyze data they have collected and draw appropriate conclusions.
4. Students will be able to apply the results of this experiment to real-world ecological and agricultural scenarios.
5. Students will be able to classify independent variables, dependent variables, and control of variables in experiments.
6. Students will be able to describe the necessary requirements for plant growth and survival.
7. Students will be able to define the critical roles that soil plays in plant development and survival.
8. Students will be able to describe the soil factors that control water and nutrient supply to plants.
9. Students will be able to apply their knowledge of differences/changes in soil factors and their relationship with plant growth.
10. Students will be able to describe the relationship between soil nutrient availability and plant tissue nutrient content.
11. Students will be able to apply their knowledge of plant tissue nutrient content describe the relationship between nutrient content and plant growth.
12. Students will be able to apply their knowledge of matter cycling to explain potential secondary effects of plant nutrition.
13. Students will be able to describe the relationship between soil nutrient availability, plant demand, and the leaching of nutrients.
14. Students will be able to assess the potential ecological implications of nutrient leaching.

**Table of Lessons:**

| Lesson Title- Brief Description | Learning Objectives | Materials |
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| **Lesson 1: Effects of Soil on Plant Growth Rate and Survival**<br>This lesson emphasizes the design of effective scientific experiments. Following an introductory activity on experimental design, students will design a simple but carefully controlled experiment to assess the effect of soil type on plant growth rates. This experiment serves as the basis from which the remainder of the lessons in the unit are derived. | In addition to objectives 1-5, listed above:<br>6. Students will be able to describe the necessary requirements for plant growth and survival.<br>7. Students will be able to define the critical roles that soil plays in plant development and survival. | • Pots for planting (one per student or group)<br>• Seeds (preferably from fast-growing plants)<br>• Growlights, a greenhouse, or a sunny window<br>• Soil-less planting media and fertilizer, or different types of soil (e.g. potting soil, unamended top soil, and sand)<br>• Ruler<br>• Datasheets and/or notebooks |
| **Lesson 2: Soil Nutrient Availability and Dynamics**<br>Students will design an investigation to assess the availability of nutrients in soil, and to track changes in availability over time. These data are then applied to the results of the plant growth experiment, giving students the opportunity to explore the relationship between soil nutrients and plant growth rates. | In addition to objectives 1-5, listed above:<br>6. Students will be able to define the critical roles that soil plays in plant development and survival.<br>7. Students will be able to describe the soil factors that control nutrient supply to plants.<br>8. Students will be able to apply their knowledge of differences/changes in soil factors and their relationship with plant growth. | • Soil test kit for nitrogen, phosphorous, and potassium, such as:<br>o LaMotte Soil Macronutrients: 5928-01<br>or<br>o LaMotte NPK Soil Test Kit: 3-5880<br>or similar. Refills may be required, depending on the number of samples.<br>• Soils from Lesson 1, **Effects of Soil on Plant Growth and Survival**, or another source of different soil types<br>• Datasheets and/or notebooks |
| **Lesson 3: Plant Tissue Nutrient Content** | In addition to objectives 1-4, listed above: | • Plant tissue test kit for nitrogen, phosphorous, |

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| In this activity, students will assess the nutrient content of plant tissues grown in different soils. Changes in plant nutrient content can be tracked over time, if desired. Students will then apply this knowledge to the results of the plant growth and soil investigations, and will describe the relationship between soil nutrient availability and tissue nutrient content, and the interactive effects of these on plant growth. | 5. Students will be able to describe the relationship between soil nutrient availability and plant tissue nutrient content.<br>6. Students will be able to apply their knowledge of plant tissue nutrient content to describe the relationship between nutrient content and plant growth.<br>7. Students will be able to apply their knowledge of matter cycling to explain potential secondary effects of plant nutrition. | and potassium, such as:<br>o LaMotte Macronutrient Plant Tissue Test Kit: 5026-01<br>or similar. Refills may be required, depending on the number of samples.<br>• Plant tissue samples from Lesson 1, **Effects of Soil on Plant Growth and Survival**, or another source of plant material<br>• Datasheets and/or notebook<br>• Scissors or another means of processing plant material |
| **Lesson 4: Nutrient Losses via Water Movement and Potential Ecosystem Effects**<br>The role of nutrient losses and eutrophication provides an introduction to the importance of nutrient movement and the role of water in nutrient cycling. Students then design and conduct an experiment to compare nutrient losses between soil types. Knowledge of these potential leaching losses is then applied to potential intra- and intersystem effects. | In addition to objectives 1-4, listed above:<br>5. Students will be able to describe the relationship between soil nutrient availability, plant demand, and the leaching of nutrients.<br>6. Students will be able to assess the potential ecological implications of nutrient leaching. | • Water test kit for nitrogen species, phosphorous, and potassium, such as:<br>o LaMotte Nitrate Nitrogen Test Kit: 3110-01<br>o LaMotte Ammonia Nitrogen Test Kit: 3304-01<br>o LaMotte Low Range Phosphate Test Kit: 7416-02<br>o LaMotte Potassium Test Kit: 3138-01<br>or similar.<br>Notes: Water test kits typically separate the ammonia test from that for nitrate. Both tests can be conducted, and the results summed to yield total inorganic nitrogen availability. Test kit packages, such |

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| | | as:<br>o LaMotte AM-12 The TesTabs Water® Investigation Kit: 5849<br>are convenient, and provide tests that may be useful in other investigations. Some kits of this sort will need to be supplemented with a separate ammonia test, if desired. Most will also require the purchase of a potassium test kit. A hydroponics test kit, such as:<br>o LaMotte Hydroponics 4-Way Test Kit: 3561<br>provides all 3 required tests.<br>• Excess water drained from potted plants used in Lesson 1, **Effects of Soil on Plant Growth Rate and Survival**, of this unit. Water used to compare water holding capacity (Lesson 2, **Soil Nutrient Availability and Water Holding Capacity**) may be used.<br>• Datasheets and/or notebooks<br>• Computer and projector<br>• Worksheets (included), if desired. |

**Safety Considerations:** Depending on the specifics of the test kit you are using, eye and/or hand protection may be recommended. Follow all instructions included with your test kit. Always have MSDS readily available.

**Evaluation Plan:** This unit is designed to increase students' familiarity with the scientific process. As such, the primary evaluation vehicle is the creation of lab reports. This can be done in a number of ways. Individual lab reports can be written for each experiment, or one large lab report can be created using data from the entire suite of lessons. If a single comprehensive lab report is created, individual portions can be submitted over the course of the experiment for feedback and to serve as formative assessment tools.

To assess student comprehension, emphasis should be placed on the discussion and conclusion sections of the lab report. In the discussion section, students should make sure to include potential explanations for the observed results, as well as the implications of these results for real-world scenarios. Prompt questions for the discussion section are provided in the **Elaborate** section of each lesson. The **Explain** section of Lesson 1 contains suggestions on how to introduce students to lab reports and a description of how to connect the lab report format with the 5E instructional model.

Alternative Evaluation Suggestions:
Students can be asked to create a lab report that combines the data from Lessons 1 and 2, assemble a scientific poster for Lesson 3, and submit the results of the experiment in Lesson 4 along with the provided worksheet.

Additionally, the student worksheet on nutrient cycling models can serve as summative assessment tool. Students can be asked to complete the worksheet as provided, or to create nutrient models of their own, using the provided model as a guide.

**Resources (websites):**
Creating a lab report can be a difficult task for a student lacking experience in the process. Many tutorials and guides exist online. A particularly useful guide for both students and teachers is the LabWrite program (http://www.ncsu.edu/labwrite/).

A worthwhile resource for both background information on experimental design, and a worksheet that can be used to guide students during the design of their experiments can be found at: http://www.longwood.edu/cleanva/images/sec6.designexperiment.pdf.

The experiments described in this unit require chemical tests for nitrogen, phosphorous, and potassium in soil, water, and plant tissue. Suggestions for each of these kits are included with each lesson, all of which can be found at: www.lamotte.com.

Images and descriptions of nutrient deficiencies:
5e.plantphys.net/article.php?id=289
www.ipmimages.org/browse/subimages.cfm?sub=766

Source for satellite images of the Great Lakes and the Gulf of Mexico:
visibleearth.nasa.gov/

**Brief description of how this unit relates to your graduate research**:
My research seeks to assess the potential effects of emerald ash borer on the vegetation dynamics and nitrogen cycling in black ash wetlands. The activities included as a part of the experiment being conducted by the students are highly correlated with the processes I am using to assess change in nitrogen dynamics in these wetlands.

In my research, we hypothesize that the loss of ash stands from wetlands and the resulting reduction in nutrient demand will yield an increase in nitrogen availability in the soil. This increase can be assessed directly, and may result in subsequent changes in the tissue nitrogen content of remaining tree species, and an increase in nitrogen exported from the wetlands. The increase in available nitrogen, along with reduced competition for light, may result in a fertilization effect that is measurable by assessing growth in remaining trees. Each of these components (growth rate, soil nitrogen availability, plant tissue nitrogen, and nitrogen in water draining from the soil) are also being assessed by the students in these experiments, along with phosphorous and potassium content of the same components. In addition, my research includes assessment of the nitrogen content of senesced leaves, atmospheric deposition of nitrogen through the forest canopy, and soil pore water nitrogen content.

The tests being conducted by the students differ from those used for my research, but are similar enough in nature that students can see the direct relationship between the processes. For example, the soil pore water and stream water we test for nitrogen content is subjected to a chemical process similar to that used in the student test kits, yielding a color change. The color change is assessed using a spectrophotometer, plotting the value on a standard curve. In similar fashion, the test kits contain a standard color scale by which the students will judge the nutrient levels in their samples. I plan to discuss these similarities throughout the unit, and provide the students with examples of the tools I use in my research. I will also discuss the additional components of the nitrogen cycle that are assessed in my research, which may serve as examples of additional studies that the students could perform (a question on which is included in the summative assessment).