

Harnessing Data for Climate Education

Using Harvard Forest Data for Science Teaching

Climate Change Education Project

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2024 Fall -2025 Spring

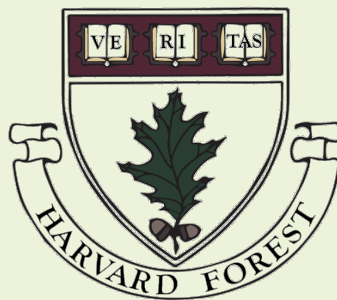


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Foreword

For many years, you—and countless students across Massachusetts—have worked alongside us to collect valuable data as part of the Schoolyard Long Term Ecological Research (Schoolyard LTER) program. In 2022, Ola, a graduate student from the Harvard Graduate School of Education (HGSE), created a [dashboard](#) using Tableau to help us better visualize this growing body of work.

We know that teachers are constantly introduced to new tools and resources, and we deeply respect the time and energy you dedicate to your students and classrooms every day. With that in mind, we'd like to gently introduce this dashboard—not as another obligation, but as a helpful and flexible tool that builds on the work you've already done. To support you, we've included a few sample activities—not as prescriptive lessons, but as optional starting points.

The dashboard does not require you to download anything. It's simply a web-based tool—just like the sites we all use every day. With just a few clicks, you and your students can select different labels and generate a variety of graphs to explore meaningful environmental patterns over time.

You are the experts. We hope this resource can serve as a useful entry point for your teaching, spark curiosity in your students, and celebrate the important contributions you've all made to our shared understanding of the natural world.

With deep gratitude,
Yvonne Chang

Learning Goals

By the end of the lessons, students will:

- Use real-world ecological data from the Harvard Forest Schoolyard LTER to observe and analyze natural patterns in local ecosystems.
- Identify and model ecosystem relationships, including how energy and matter move among producers, consumers, decomposers, and abiotic elements (air, water, soil).
- Analyze environmental changes and human impacts by interpreting datasets related to forest growth, carbon storage, or seasonal changes.
- Practice scientific inquiry and data literacy by collecting, graphing, and interpreting field data.
- Connect their local environment to broader scientific concepts, reinforcing the idea that ecosystems are dynamic systems influenced by both natural processes and human activity.

Relevant Massachusetts Science Standards (Grade 5-7)

The lesson will align with Massachusetts Curriculum Frameworks for Science and Technology/Engineering by integrating Earth and Life Science topics, specifically focusing on ecosystems, energy transfer, and human-environment interactions. Students will explore nature using real-world data from the Harvard Forest Schoolyard LTER database, promoting hands-on, inquiry-based learning.

This lesson supports the development of key Science and Engineering Practices, particularly:

- Practice 1: Asking questions and defining problems
- Practice 4: Analyzing and interpreting data

These practices are embedded throughout the lesson as students pose ecological questions, examine field data, and interpret patterns in local ecosystems. For a full list of practices, see Appendix I of the 2016 Massachusetts Curriculum Framework for Science and Technology/Engineering.

Connections to grade-level standards include:

- Grade 5 Life Science (5-LS2-1): Developing models to describe the movement of matter in ecosystems.
- Grade 5 Earth Science (5-ESS2-1, 5-ESS3-1): Understanding the water cycle and human impact on Earth's resources.
- Grade 6 Earth Science (6.MS-ESS2-3): Analyzing maps and patterns in nature to

understand Earth's changing systems.

- Grade 6 Life Science (6.MS-LS2-3, 6.MS-LS2-4): Exploring the transfer of energy in ecosystems and how disturbances affect populations.
- Grade 7 Life Science (7.MS-LS2-1, 7.MS-LS2-4): Investigating population changes and human/environmental interactions in ecosystems.

Lesson Overview

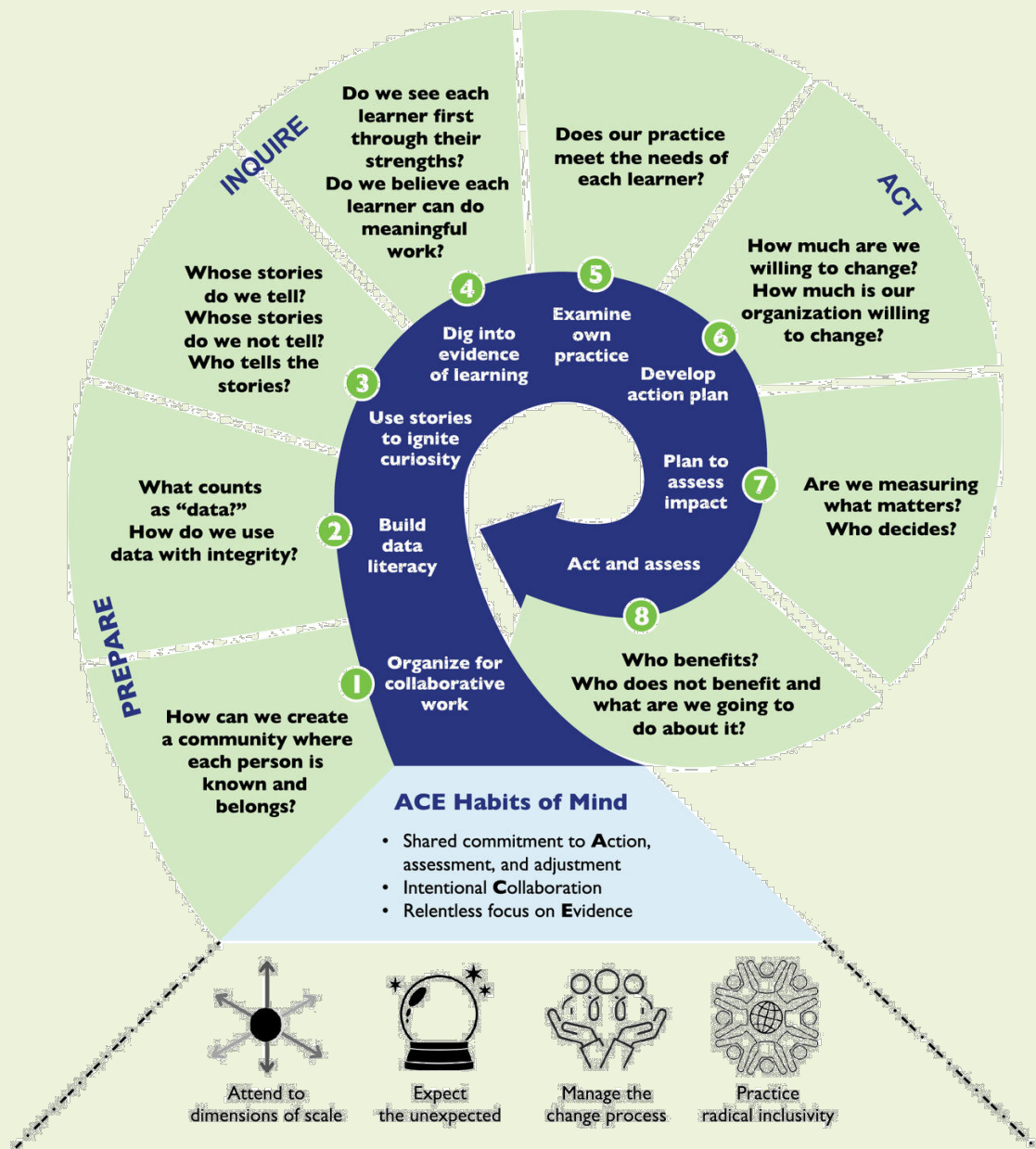
This lesson follows the [Data Wise Improvement Process](#), guiding students to explore local ecosystems using real-world data from the Harvard Forest Schoolyard LTER. Students will ask scientific questions, analyze data, and take action by making observations and drawing conclusions about the interactions within ecosystems.

Lesson Duration: 3 Classes/ week (~40-45 minutes each)

Data Wise Framework Adaptation

The lesson plan follows three key phases of the Data Wise model:

- Prepare
 - Organize for Collaborative Learning: Engage students in understanding the importance of data in science.
 - Build Assessment Literacy: Teach students how to read, interpret, and analyze environmental data.
- Inquire
 - Identify a Focus Area: Guide students to explore a key ecological question using Harvard Forest data.
 - Analyze Data: Teach students how to visualize patterns and interpret findings.
- Act
 - Plan Next Steps: Discuss findings, reflect on learning, and propose actions related to environmental sustainability.



Data Wise Framework

Phase 1: Prepare – Building Data Literacy

Objective: Introduce students to ecological data and its importance in studying nature.

Step 1: Hook Activity (15 min) – “What’s Happening in Our School?”

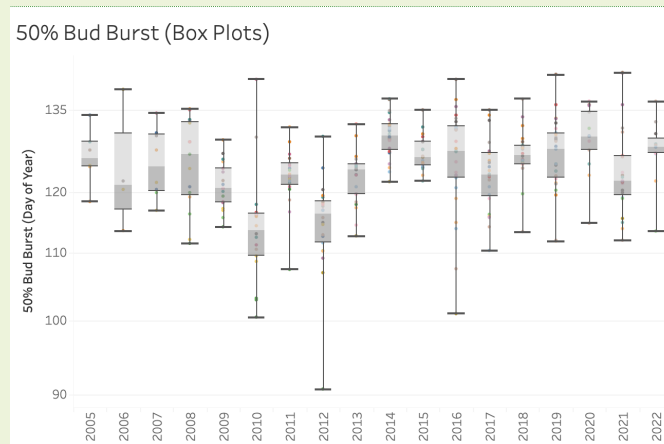
- Show images or short videos of school in different seasons.
- Ask students:
 - *What do you observe?* (E.g., different leaf colors, animals, snow, rainfall.)
 - *What do you wonder?* (E.g., Why do trees change color? How do animals survive winter?)
 - What patterns do you notice?
- Write down their responses on the board.

Teacher Prompt:

Scientists use data to track patterns in nature – and so do we! Today, we’ll explore how the data we collected, along with data from the Harvard Forest, helps us answer these questions.

Step 2: Understanding Data (20 min) – Hands-on Mini-Lesson

- Introduce the Harvard Forest Schoolyard LTER Database:
 - Explain what data is (information collected to help us learn!).
 - Explain how to read different types of graphs (line graphs, box plots).
- Example of Explanation (Subject to Change According to Grade Level):*
- Let’s break down the box plot in a simple way!*
- *The middle line inside the box shows the median – that’s the middle point of all the data.*
 - *The box itself shows the range where most of the data falls – it’s like the main ‘home’ for the data.*
 - *The lines (whiskers) sticking out from the box show how spread out the data is – kind of like stretching your arms to see how far you can reach!*
 - *The little dots outside the whiskers are called outliers – these are unusual data points that don’t fit the usual pattern, like a tree that blooms way earlier or later than most others.*
- Show a simple graph from the Tableau dashboard data (e.g., buds burst, leaves fall, and growing season).



Example Chart

[How to access the graphs? Please refer to the [Tableau Dashboard Guide](#).]

- Discuss: *How did we collect data?* (Buds, Leaves, and Global Warming)
- Activity:
 - Hand out sample data tables or graphs from the [Tableau Dashboard](#).
 - Students work in pairs to describe what they see in the data.
 - Example questions:
 - What patterns do you notice in the data?
 - Does bud burst or leaf fall vary across different months or years?

What factors might explain these changes?

Step 3: Class Discussion (10 min)

- Group share-out: Each pair shares one interesting thing they found in the data.
- Discussion prompts:
 - What does this data tell us about nature?
 - How could we use data to help the environment?
- Brainstorm Scientific Questions:
 - Example Question: How does temperature affect bud burst—and what other factors might influence it?

Possible Influencing Factors:

- *Temperature Changes*
Warmer winters and early springs can lead to earlier bud bursts.
Colder springs may delay the process.
- *Precipitation and Snow Cover*
Heavy snowfall can prolong soil insulation and delay spring warming, slowing bud burst.
Less snow may lead to earlier warming and earlier budding.
- *Climate Change Trends*
Rising global temperatures are contributing to long-term shifts toward

earlier bud bursts.

- *Extreme Weather Events*

Sudden cold snaps or unseasonal heatwaves may disrupt normal budding patterns.

- *Tree Species Variation*

Different tree species respond uniquely to changes in temperature, precipitation, and seasonal cues.

- Write 2-3 student-generated questions on the board for tomorrow's data investigation

Phase 2: Inquire – Exploring Data

Objective: Students analyze real data to discover patterns and relationships in ecosystems.

Step 4: Investigating the Data (30 min)

1. Introduce the Research Question
 - “Let’s explore how seasonal changes affect plants!”
 - Choose a dataset, such as:
 - Tree Growing Season Over Time (How does it change in winter vs. summer?)
 - Bud Burst/ Leaves Fall Data (Seasonal Plant Changes)
2. Hands-on Data Exploration
 - Split students into small groups (3-4 students per group).
 - Provide each group with one dataset (printed or digital).
 - Students graph and interpret their data:
 - Graphing Options: Paper graphs, Google Sheets, or an online graphing tool.
 - Data Prompts:
 - What trend do you see in your graph?
 - What trends do you notice in bud burst/ leaf fall over time?
 - Are there certain years when bud burst, or leaf fall happens earlier or later? What might explain that?
 - How might patterns in bud burst and leaf fall relate to global temperature changes?
3. Create a Scientific Model (20 min)
 - Each group will create a scientific model that illustrates how changes in bud burst or leaf fall might affect other parts of the ecosystem.
 - Options for models include:
 - A seasonal timeline showing the chain reaction of early/late bud burst or leaf fall
 - A simplified energy flow diagram showing how plant changes affect other organisms
 - A cause-and-effect chart linking climate patterns (e.g. global warming) to plant behavior
 - Example prompts to guide student thinking:
 - If bud burst happens earlier in the year, how might it affect:
 - Animals that rely on young leaves for food?
 - The timing of insect hatching or bird migration?
 - If leaf fall is delayed, how might that influence:

- Soil temperature and moisture levels?
- Decomposition rates and nutrient cycling?
- How might warmer temperatures change the entire cycle of growth and dormancy for trees?

Step 5: Student Discussion & Argument from Evidence (15 min)

- Each group presents their findings to the class.
- Discussion Prompts:
 - What surprised you about your data?
 - What new questions do you have?
 - How might humans impact these patterns?
- Connection to Local Environments:
 - Do we see these same patterns near our community?

Phase 3: Act – Applying Learning

Objective: Students apply their learning to real-world environmental issues.

Step 6: Connecting Data to Human Impact (20 min)

- Mini-Lesson: How do humans affect tree growth and seasonal changes?
 - Show examples of deforestation, urbanization, and climate change.
 - Discuss how tree growth affect the air we breathe and wildlife habitats.
- Guided Student Discussion:
 - What happens if trees don't grow as expected?
 - How does climate change impact forests?
 - What can we do to help?

Step 7: Student Action Project (30 min)

Students choose ONE action to apply their learning (details see [Brainstorm Guide](#)):

1. Data & Graphing Exploration
2. School-Level Exchange: Comparing Local Ecosystems
3. Empathy Walk: Seeing Nature Through Different Perspectives
4. Reading in Nature & Nature Journaling
5. Nature Scavenger Hunt: Interactive Exploration
6. Data JEM Activity: Hudson Data Jam-Inspired Project

Step 8: Reflection & Assessment (15 min)

- Exit Ticket Questions:
 1. What did you learn about ecosystems from this lesson?
 2. How did using data help you understand nature better?
 3. What's one thing you can do to help your local environment?
- Teacher Observation Checklist:
 - Student participation in group work
 - Accuracy of graphs and models
 - Depth of discussion and engagement in analysis

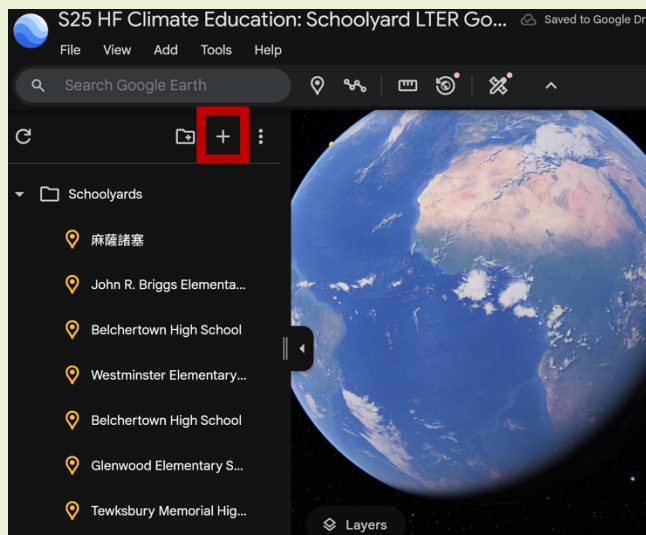
Lesson Wrap-Up & Next Steps

Extension Ideas

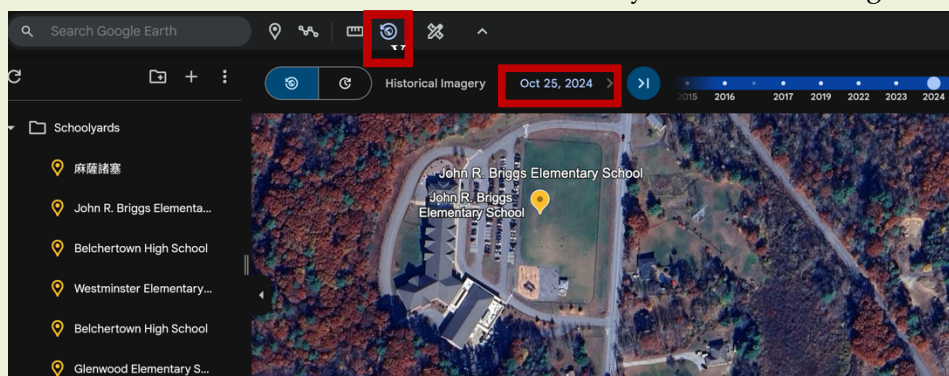
- Outdoor Connection: Take students outside to collect real data!
 - See example activities from [Brainstorm Guide](#)
- Technology Integration: Use [Google Earth](#) to map tree coverage in different locations/ years.
- Community Engagement: Share findings with parents or local environmental groups.

Materials & Resources

- [Schoolyard LTER Buds, Leaves and Global Warming Tableau Dashboard](#)
- [Harvard Forest LTER Data Sets](#)
- [Example Mini Lesson](#) (with presenter notes)
- [Google Earth](#)



Click the "+" button, enter school's address to add your school to Google Earth.



Click this icon and drag the timeline to view changes in the landscape across different years from a bird's-eye view.

Activities Brainstorm Guide

Engaging Activities to Deepen Scientific Inquiry & Environmental Awareness

Introduction

This guide provides creative activities for students to engage with nature, data, and environmental science through hands-on experiences. Activities encourage observation, critical thinking, collaboration, and action, allowing students to interact with their environment while developing scientific inquiry skills.

Students will:

- Analyze real-world environmental data.
- Engage in creative exploration through journaling, drawing, and storytelling.
- Connect with students from another school to exchange insights.
- Apply social science skills through empathy-building activities.

1. Data & Graphing Exploration

Activity: Analyzing School-Level Environmental Data

Students will receive real ecological data from a school outside their own and interpret patterns.

Note: You may focus on Brooklyn Technical High School, St. Mary's Parish School, Williston Northampton School, as well as sites in Tewksbury, Belchertown, and Drumlin Farm, as they have contributed more consistent, long-term data over the years.

Steps:

1. Pick a random school from an environmental database (e.g., Hudson Data Jam or Harvard Forest Schoolyard LTER).
2. Provide students with a graph (e.g., buds burst, leaves fall, growing season).
3. Ask them to analyze trends and compare them with their own local environment.
4. Discuss:
 - What environmental differences might cause these patterns?
 - How does their school's location affect data trends?
 - What predictions can they make for the future?

Extensions:

- Create an infographic that compares the environmental conditions of your school and your partner school.
- Write a letter to students at the other school sharing their analysis.

Data & Graphing Exploration Worksheet

Step 1: Explore the Data

You have received data from another school about **growing season/ bud burst/ leaf drop**. Observe the graph carefully and answer the following:

Data Interpretation

1. What trends do you see in the growing season length?

2. How does the bud burst timing compare to your local environment?

3. When does leaf drop occur at the other school? Is it earlier or later than in your region?

Comparing Locations

4. What factors might cause differences in bud burst and leaf drop between the two schools? (Consider temperature, latitude, or other environmental factors.)

5. Based on the data, do you think the growing season at your school is changing over time? Why or why not?

Step 2: Predict & Explain

Future Predictions

6. If climate change continues, based on your observations of the data, how might bud burst and leaf drop be affected in the future?

7. What impact do these seasonal changes have on animals or other plants in the ecosystem?

Communicating Findings

8. Write a short message to a student at the other school explaining how your growing season compares to theirs. Include one question you'd like to ask them about their data.

2. School-Level Exchange: Comparing Local Ecosystems

Activity: Virtual or Pen-Pal Exchange with Another School

Students will connect with a class from another region to share findings on their local environment.

Steps:

1. Partner with another school in a different state or county.
2. Share graphs, journals, and photos of their schoolyard's ecosystem.
3. Compare and contrast: What are the biggest differences in nature?
4. Reflection discussion: How do human and natural factors impact each school's environment differently?

Extensions:

- Host a video call with the partner class to present findings.
- Create a collaborative nature blog to document discoveries.

Note:

Considering potential communication barriers for students, we suggest facilitating inter-school communication through teachers. Our monthly meetings are also a great platform for this!

School-Level Exchange Worksheet

Step 1: Observing Local Seasonal Changes

Your school and a partner school are sharing data on **growing season, bud burst, and leaf drop**. Before comparing, take a moment to analyze your own school's environment.

1. When does bud burst typically occur at your school?

2. How long does the growing season last?

3. When do trees start to drop their leaves?

4. What factors influence these seasonal changes in your area? (Consider temperature, altitude, latitude, etc.)

Step 2: Comparing Data with Your Partner School

Review the growing season, bud burst, and leaf drop data from your partner school. Answer the following:

1. What is the biggest difference in bud burst timing between your school and the partner school?

2. How does their growing season compare to yours? Is it longer or shorter?

3. When does leaf drop occur at their school? How does this compare to your school?

4. What might explain these differences?

Step 3: Communicating with Your Partner School

Write a short letter to a student at the partner school sharing your observations and asking a question about their environment.

Dear Student at [Partner School Name],

My name is _____, and I am writing from [Your School Name]. I noticed that in your area, bud burst happens around _____, while in my school, it usually happens around _____. It was interesting to see that your growing season is _____ compared to ours. One question I have for you is: _____?

Looking forward to your response!

Sincerely,

Step 4: Reflection

1. How do you think climate change could impact the differences you observed?

2. What actions can schools take to monitor and document these seasonal changes in the future?

3. Empathy Walk: Seeing Nature Through Different Perspectives

Activity: The Social Science of Environmental Change

Students explore how different people interact with nature in their community. They walk around a local park or schoolyard and take on different perspectives:

- A scientist observing natural patterns.
- A bird or insect experiencing the landscape from an animal's view.
- A historian thinking about how the land looked 100 years ago.
- A city planner considering how development has shaped the environment.

Steps:

1. Assign students a perspective role before their walk.
2. During the walk, students take notes, sketches, or photos based on their perspective.
3. Class discussion:
 - How did different roles change their experience?
 - What human impacts were most noticeable?
 - How can we balance urban development with environmental preservation?

Extensions:

- Write a short story or poem from the perspective of their assigned role.
- Debate: If you were a city planner, how would you design the area differently?

Empathy Walk Worksheet

Step 1: Assigning a Perspective

Choose one of the following perspectives before going on your empathy walk. Observe your environment through this lens and take notes.

- A scientist studying seasonal changes
- A bird experiencing the landscape from an animal's view
- A historian imagining how this land looked 100 years ago
- A city planner considering how development has shaped the environment

Which perspective did you choose?

Step 2: Observing Bud Burst, Growing Season, and Leaf Drop

1. Look around your schoolyard or local park. What signs of **bud burst** do you see (if in spring), or what signs of **leaf drop** do you notice (if in autumn)?
-

2. Estimate the growing season based on what you observe. Are trees still actively growing, or do they seem dormant?
-

3. How might animals in this ecosystem be affected by these seasonal changes? Consider food sources, shelter, and migration patterns.
-

4. Take a sketch, photograph, or write a brief description of something that stands out to you during your walk.
-

Step 3: Perspective-Based Reflection

5. How does your chosen perspective influence the way you see seasonal change?
-

6. If you were a city planner, how would you design this space to better support trees and wildlife during seasonal transitions?
-

7. Imagine you are a historian: How might seasonal patterns have changed over the past century due to climate shifts or human activity?

8. What human impacts are visible in the area you walked through? How do they influence the local growing season?

Step 4: Creative Expression

Choose one of the following ways to express your experience:

- Write a short story from the perspective of your assigned role.
 - Compose a short poem about the changes you observed.
 - Create a visual representation (drawing, map, or infographic) of your observations.
 - Develop a proposal suggesting small environmental improvements based on your observations.
-

Step 5: Discussion & Future Considerations

9. How do you think climate change could impact **bud burst, growing season, and leaf drop** in the future?

10. What actions could your school or community take to better protect trees and local biodiversity as seasons change?

4. Reading in Nature & Nature Journaling

Activity: Outdoor Book Club and Observation Journal

Students read a nature-themed book in small groups and combine it with scientific journaling.

Steps:

1. Choose a book related to nature (examples below).
2. Students read in a quiet outdoor space such as a park or schoolyard.
3. Nature Journaling:
 - Draw plants, trees, or animals they observe.
 - Describe what they hear, smell, or feel.
 - Connect book themes to their real-world environment.
4. Class discussion on the reading and their observations.

Book Recommendations (By Age Level):

For younger students (Grades 5-6):

- The Hidden Life of Trees (Young Readers' Edition) – Peter Wohlleben
- The Boy Who Grew a Forest – Sophia Gholz

For older students (Grades 7+):

- Braiding Sweetgrass for Young Adults – Robin Wall Kimmerer
- *The Wild Robot* – Peter Brown (5th Grade)

Extensions:

- Create a “Sound Map” of what they hear outdoors.
- Write a reflection: How does nature affect our emotions and thinking?

Reading in Nature & Nature Journaling Worksheet

Step 1: Preparing for Outdoor Reading

Choose a nature-themed book from the provided list or one of your own. Find a quiet outdoor space where you can read and observe seasonal changes.

Book Title: _____

Step 2: Observing Seasonal Changes

As you read outdoors, take a moment to observe the trees and plants around you.

1. Are there signs of **bud burst** (if in spring) or **leaf drop** (if in autumn)? Describe what you see.

2. What colors, shapes, or textures stand out in the natural environment?

3. Listen carefully. What sounds do you hear? (Wind, birds, rustling leaves, etc.)

4. How does being in nature affect your focus and emotions while reading?

Step 3: Nature Journaling

Use this space to document your observations through writing, sketches, or diagrams.

- Draw a leaf, tree, or plant you see. Label any visible seasonal changes.

- Write a short description of how the environment is shifting during this time of year.

Step 4: Connecting the Book to Your Observations

1. How does the book's theme relate to what you are seeing in nature?

2. What parallels can you draw between the characters' experiences and seasonal changes in the environment?

3. If the author could visit your reading spot, what would they notice about the natural setting?

Step 5: Creative Reflection

Choose one of the following:

- Write a poem or short story inspired by what you read and observed.
- Create a "Sound Map" by illustrating where different natural sounds are coming from around you.
- Design a journal page that combines quotes from your book with sketches and notes on nature.

Step 6: Discussion & Future Inquiry

1. How might seasonal patterns like bud burst and leaf drop change in the future due to climate shifts?

2. What role does literature play in helping us connect with and understand the natural world?

5. Nature Scavenger Hunt: Interactive Exploration

Activity: A Science-Based Hunt for Patterns in Nature

Students search for natural patterns in their local environment while recording data. This promotes observation skills, data collection, and scientific curiosity.

Steps:

1. Provide a checklist of environmental features to find (or let students create their own).
2. Students hunt for examples of:
 - Different leaf shapes and colors
 - Insects or birds interacting with plants
 - Signs of water movement (streams, puddles, wet soil)
 - Tree rings or evidence of past tree growth
3. Students take notes and sketches in their journals.
4. Data Discussion:
 - What patterns did they find?
 - How does the local ecosystem support biodiversity?

Extensions:

- Graph the number of species found and discuss biodiversity levels.
- [Example Worksheet](#) from Harvard Arnold Arboretum.

6. Data Jam Activity: Hudson Data Jam-Inspired Project

Activity: Transforming Data into a Creative Story

Students turn real ecological data into a creative story, poem, or song, inspired by the [Hudson Data Jam Competition](#).

Steps:

1. Choose a Harvard Forest dataset (e.g., buds burst, leaves fall, growing season).
2. Students interpret the data and identify trends.
3. Instead of writing a science report, they must tell a creative story about the data:
 - What if trees could talk? What would they say about climate change?
 - Write a poem about the journey of a raindrop through the forest.
 - Create a comic strip about a leaf's life cycle.
4. Students present their data stories to the class.

Extensions:

- Turn stories into a digital book or class website.
- Host a "Data Jam Showcase" where students perform their poems, raps, or skits.

Guide for Teachers: Data Dashboard in Tableau

Introduction

This guide will help teachers navigate and use the Harvard Forest data visualization in Tableau to explore fall phenology trends. The interactive tool allows users to examine data on leaf fall timing across different schools, elevations, and surrounding areas in Massachusetts.

Tableau Visualization Link: [Schoolyard LTER Tableau Dashboard](#)

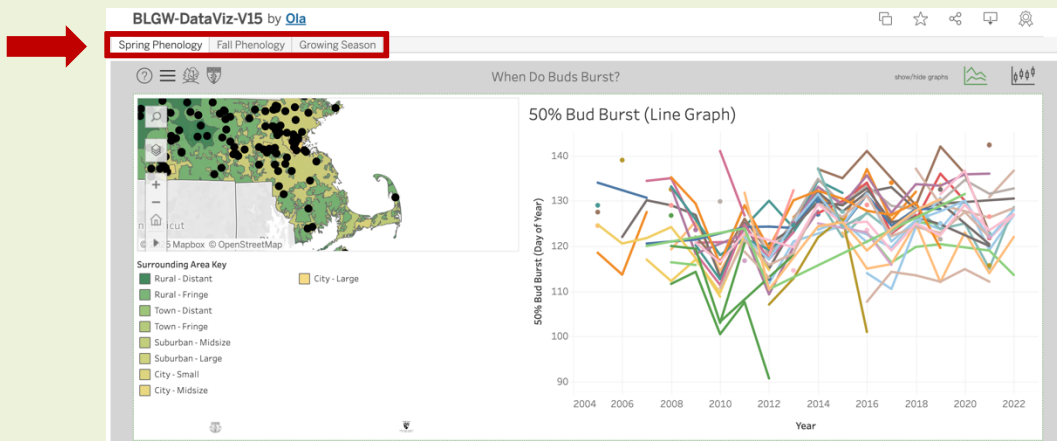
How to Use the Tableau Dashboard

1. Navigating Between Different Tabs

The visualization has three tabs at the top:

- **Spring Phenology** – Data on budburst and leaf-out.
- **Fall Phenology** – Data on leaf fall timing.
- **Growing Season** – Data on the length of the growing season.

Click on each tab to switch views.



2. Understanding the Phenology Dashboard

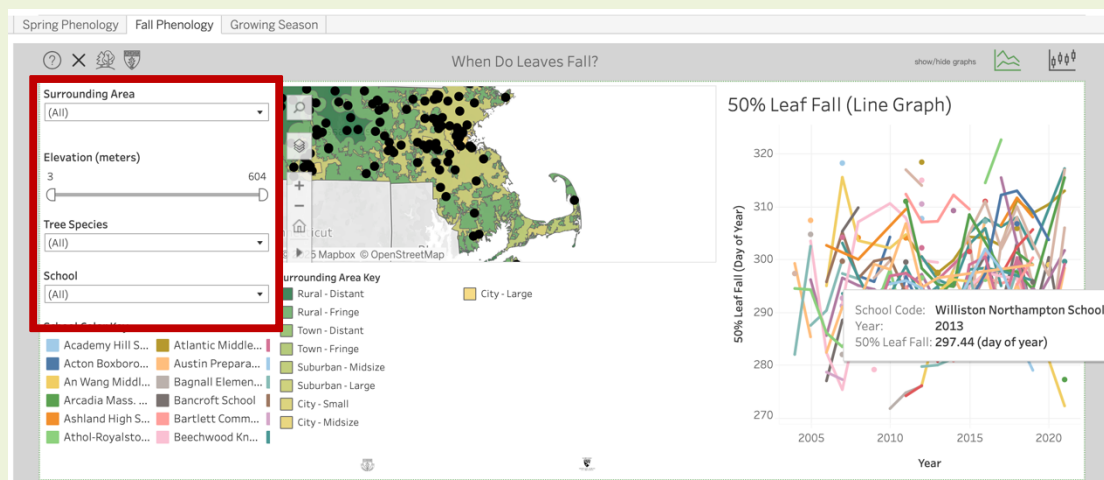
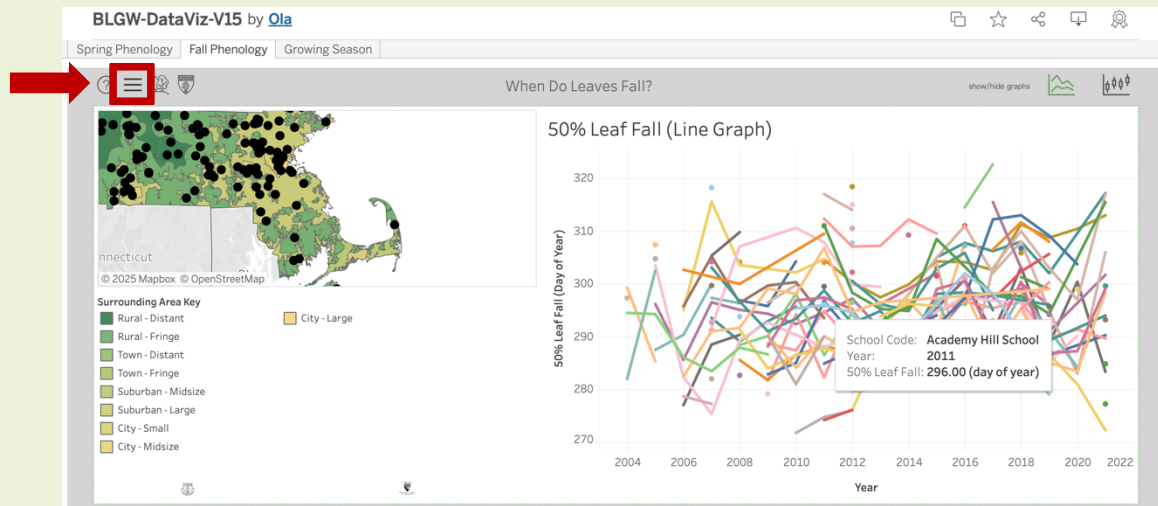
The “Fall Phenology/ Spring Phenology/ Growing Season” tab contains two main components:

- **Map View:** Displays different school locations and their surrounding area types.
- **Line Graph:** Shows the 50% leaf fall timing trends over time.
- **Box Plot:** Understand the Distribution of the data.

Filters on the Left Panel

Teachers can customize the displayed data using the following filters:

- **Surrounding Area:** Select rural, town, suburban, or city locations.
- **Elevation (meters):** Adjust the slider to filter data by elevation.
- **Tree Species:** Choose specific species or view all.
- **School:** Filter data for a specific school.

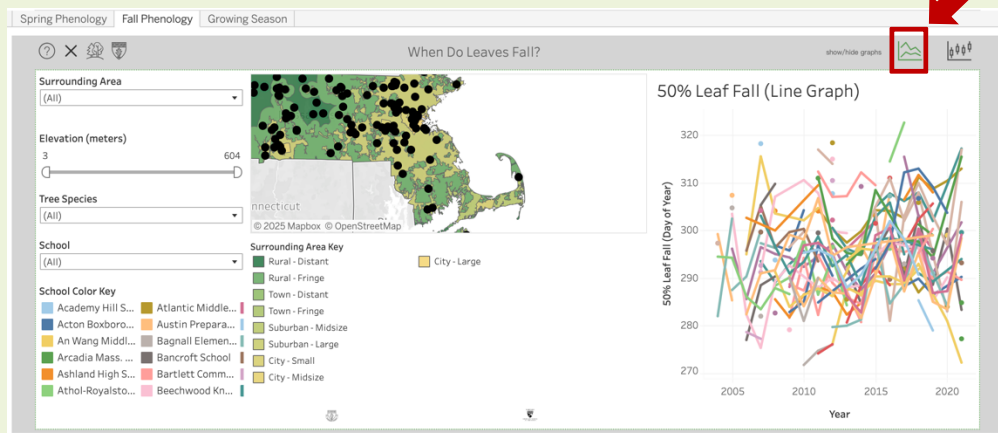


Understanding the Map

- Black dots represent data collection points.
- The map background is color-coded based on surrounding area types (e.g., rural, suburban, city).
- Zoom in and out using the $+$ / $-$ buttons or pan by clicking and dragging.

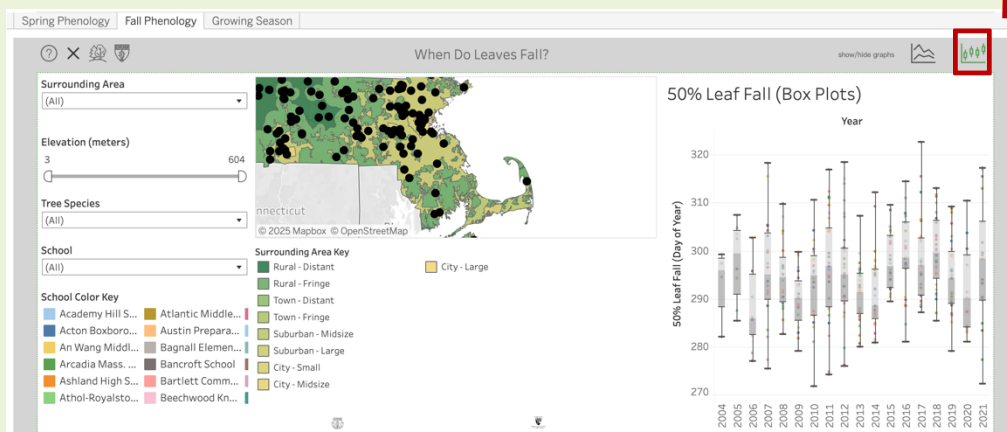
Reading the Line Graph

- The x-axis represents the **year** (2000–2020).
- The y-axis represents the **day of the year** when 50% of leaves have fallen.
- Each colored line represents data from a different school.
- Hover over a line to see details about a specific data point.



Reading the Box Plot

- The x-axis represents the year (2000–2024).
- The y-axis represents the day of the year when 50% of buds burst (or other phenological events).
- Each box plot summarizes the distribution of data for a given year, showing the median, quartiles, and range.
- The box represents the interquartile range (IQR) (25th to 75th percentile).
- The horizontal line inside the box represents the median (50th percentile).
- The whiskers extend to the smallest and largest values within 1.5 times the IQR.
- Dots outside the whiskers indicate outliers, which represent extreme data points.
- Hover over a box plot to see details about a specific data point.



Global Climate Change Education Practices

Project-Based Climate Change Curriculum

Interdisciplinary project-based learning (PBL) offers an effective solution by connecting knowledge to real-world applications, promoting holistic understanding, and enhancing student responsibility toward climate issues.

Malaysia demonstrates the potential of structured, inquiry-based learning to improve climate change knowledge and pro-environmental attitudes through its 5E learning cycle-based curriculum. Activities such as greenhouse effect experiments and energy-efficient home designs, supported by teacher training, help students connect scientific concepts with real-world challenges. A study involving 115 Grade-5 students found that the treatment group significantly outperformed the control group in both knowledge and pro-environmental attitudes, with behavioral changes like reduced electricity use sustained over time.

The Philippines and India have implemented hands-on learning initiatives to foster environmental awareness and action. The Philippines' Climate Change and Environmental Education (CCEE) initiative engaged students, teachers, and local government officials in activities such as tree planting, school gardening, and waste management. Schools reported increased student involvement in recycling and biodiversity initiatives. In India, the Paryavaran Mitra program guided over 218,000 schools through action-based projects on biodiversity, water conservation, and waste management. The structured five-step pedagogy—Explore, Discover, Think, Act, and Share—empowered students to lead sustainability initiatives within their communities.

The Enviroschools Programme in **New Zealand** integrates project-based learning with cultural responsiveness, fostering sustainable practices and critical thinking. The program engages over 1,200 schools, improving environmental literacy through a four-stage action-learning framework: identifying issues, exploring solutions, taking action, and reflecting on progress. Outcomes include 90% of participating schools contributing to biodiversity initiatives and 72% reporting positive impacts on families and communities.

Localized, hands-on projects in **Greece and Canada** demonstrate the effectiveness of climate change education in enhancing environmental literacy and promoting behavioral change. In Greece, an energy efficiency program engaged students in energy audits and renewable energy projects, successfully fostering energy-saving behaviors. Similarly, Canada's "Jeunes Visionnaires" project involved middle school students in mapping local climate impacts, analyzing ecological changes, and planning sustainable solutions. By the

end of the project, a majority of participants could accurately explain the greenhouse effect, and 90% reported increased awareness of actionable environmental behaviors.

Integrated Climate Literacy Through Core Curriculum

Embedding climate change education into core subjects provides a scalable and cost-effective policy approach for fostering sustainability awareness, critical thinking, and real-world problem-solving skills.

India and Guatemala provide compelling examples of embedding climate change education into existing curricula. In Guatemala, climate literacy topics are incorporated across foundational subjects such as natural sciences and mathematics. Activities such as deforestation mapping and environmental mathematics enable students to connect classroom learning with pressing local environmental challenges. The whole-school model actively involves teachers, students, and community stakeholders in achieving shared environmental goals.

In **India**, the Coimbatore study demonstrates how climate education can be seamlessly embedded into social studies through targeted multimedia tools. An animation-based educational video was developed to teach fourth and fifth graders about global warming and climate change within the social studies curriculum. The study revealed significant improvements in application-level learning outcomes, with the experimental group achieving higher scores than the control group. This approach contextualized environmental issues within subjects already studied, ensuring retention and practical application.

The Stanford Climate Change Education Project in the **U.S.** integrates climate change topics into standard Earth science and environmental systems lessons, aligned with Next Generation Science Standards (NGSS). Students engage in analyzing real-world climate data, conducting experiments, and structured discussions. Teachers receive targeted professional development, enabling seamless incorporation of these materials into classrooms without additional instructional time.

In **Florida**, an interdisciplinary approach to climate change education integrates geography, math, and science, emphasizing local climate impacts such as sea-level rise. Activities include mapping geographic changes, calculating affected areas using geometry, and analyzing climate data. The interdisciplinary design has been particularly effective for underrepresented groups in STEM.

Singapore embeds climate change education across geography, science, social studies, and economics, fostering interdisciplinary learning. Geography students analyze climate change through case studies, while science students explore greenhouse gas emissions and

renewable energy. Social studies lessons focus on sustainable development policy analysis, equipping students with a broader understanding of the societal implications of environmental challenges.

Building Climate Literacy Through Professional Development

Professional development in climate change education (CCE) equips teachers with the knowledge, skills, and tools necessary to deliver effective, locally relevant climate education.

In **South Africa**, the Keep-It-Cool Climate Change Education (KIC-CCE) initiative trained Geography teachers to incorporate climate change adaptation and mitigation strategies into their lessons. Over a five-day intensive workshop, teachers learned to use local environmental examples to make lessons more engaging. Professional learning communities (PLCs) were established to encourage peer collaboration and sustain progress. Teachers reported significant improvements in their ability to teach climate change, and students-initiated projects such as waste management systems.

Canada offers effective short-term professional development programs. The Ecosage Circle, a six-day program held throughout the school year, trained teachers in integrating climate science into classrooms while modeling pro-environmental behaviors. Outcomes showed that 85% of participants adopted environmental actions like reducing energy use and recycling. Similarly, the Mutants' Circle program encouraged teachers to experiment with climate-friendly behaviors in their personal lives and reflect on their experiences, increasing their confidence and environmental responsibility.

The U.S. offers several climate change teacher training programs. The NGSS-aligned professional development program in Maryland and Delaware focuses on integrating technology and regional climate phenomena into K-12 curricula. The SUCCEED program at Carnegie Mellon University provides science and math teachers with immersive workshops combining lectures, laboratory activities, and field trips. NASA's CYCLES program tailors climate education for Native American communities, integrating local climate data and indigenous perspectives into lessons. These programs emphasize interdisciplinary learning, cultural relevance, and hands-on experiences, offering comprehensive insights for empowering educators globally.

Reference: [Global Challenges, Local Solutions: Sustainability](#)