# Data: fair or misleading?

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| **Focus question** | How do farmers use scientific data to make informed decisions about food production, resource management, and sustainability? |
| **Learning target** | Students will analyze and interpret agricultural data to identify patterns, make predictions, and construct scientific explanations through argumentation. They will use data visualization techniques to support evidence-based decision-making in real-world farming scenarios. |
| **Vocabulary** | Correlation vs. causation, variables, evidence-based argument, scatter plot, histogram, pie chart, line graph, scale, axes, yield, composition, irrigation, biotechnology, biofuels, sustainability, total mixed ration (TMR), lactating |

## MS-LS2 Ecosystems: Interactions, Energy, and Dynamics
## MS-ESS3 Earth and Human Activity
## MS-ETS1 Engineering Design
## MS-PS3 Energy

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| **Performance expectation** MS-LS2–1 | **Classroom connection:** Students will analyze agricultural data to determine how factors such as soil quality, water availability, and population density impact farming. |
| **Performance expectation** MS-ESS3–3 | **Classroom connection:** Students will use real-world datasets to explore how sustainable farming practices can reduce environmental impact. |
| **Performance expectation** MS-ETS1–1 | **Classroom connection:** Students will evaluate agricultural data to propose solutions for improving efficiency in food production while considering economic and environmental constraints. |
| **Performance expectation** MS-PS2–4 | **Classroom connection:** Students will analyze data related to biofuels and energy efficiency in farming, investigating how different fuel sources impact energy transfer in agricultural production. |

## Science and engineering practices

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| **Analyzing and Interpreting Data** | **Classroom connection:** Students analyze agricultural datasets to identify patterns and make data-driven recommendations for sustainable farming practices. |
| **Constructing Explanations and Designing Solutions** | **Classroom connection:** Students construct explanations based on real-world data and propose solutions for improving crop production, water conservation, and soil health while balancing economic and environmental constraints. |
| **Using Mathematics and Computational Thinking** | **Classroom connection:** Students use statistical methods, proportional reasoning, and graphical analysis to determine relationships between variables. |
| **Engaging in Argument from Evidence** | **Classroom connection:** Students present their data-driven recommendations to "farmers" using their graphs and scientific reasoning to support their claims. |

## Disciplinary core ideas

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| **ESS3.C: Human Impacts on Earth Systems** | **Classroom connection:** Students analyze how fertilizer use affects soil health, water quality, and sustainable farming practices. |
| **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** | **Classroom connection:** Students explore how soil quality impacts nutrient cycling, plant growth, and long-term agricultural productivity |
| **ESS2.C: The Roles of Water in Earth's Surface Processes** | **Classroom connection:** Students investigate how water quality influences fish populations, aquatic ecosystems, and farm sustainability |
| **ESS2.D: Weather and Climate** | **Classroom connection:** Students examine how temperature variations affect dairy farm milk production and seasonal product demand |
| **LS3.A: Inheritance of Traits** | **Classroom connection:** Students analyze the role of genetic modifications |
| **LS2.A: Interdependent Relationships in Ecosystems** | **Classroom connection:** Students evaluate the balance between agricultural productivity, ecosystem stability, and population growth |
| **PS3.D: Energy in Chemical Processes and Everyday Life** | **Classroom connection:** Students compare the energy efficiency, cost, and environmental impact of biofuels versus conventional fuels |

## Cross-cutting concepts

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| **Cause and Effect** | **Classroom connection:** Students analyze how different agricultural practices cause changes in crop production, soil health, and environmental sustainability. |
| **Patterns** | **Classroom connection:** Students identify patterns in agricultural data to make predictions and recommendations. |
| **Stability and Change** | **Classroom connection:** Students investigate how changes in farming techniques impact long-term agricultural sustainability and food production |
| **Systems and System Models** | **Classroom connection:** Students explore how farms function as systems where multiple factors interact to influence productivity. |

This lesson is aligned to be used to meet several Common Core performance expectations as well: 6.EE.C.9, 7.RP.A.2, and 8.SP.A.1.

# Background

For centuries, farmers have relied on data—whether recorded in notebooks or collected through modern digital tools—to make critical decisions about their crops, livestock, and land management. In fact, some of the oldest artifacts of written information are data sets and drawings presumably made by farmers keeping track of their crops and animals. Today, advancements in agricultural science and technology provide farmers with access to a vast amount of data, from soil composition and weather patterns to market prices and yield predictions. However, just as data can be a powerful tool for informed decision-making, it can also be misleading when presented inaccurately or with bias.

In this activity, students will be presented with a series of visuals through a gallery walk to determine whether or not the information depicted within the data visualization is fair or misleading. Then, students will be divided into groups and given a scenario. After researching the scenario and analyzing given data, students will create their own visualization and presentation for communication with the class of "farmers". This presentation should include a fair data visualization yet still persuade the farmer to make the best decision for the scenario.

**What makes a graph "fair" or "misleading"?**

A graph is "fair" when it presents data accurately, using appropriate scales, labels, and representations that allow viewers to interpret the information objectively. A misleading graph, on the other hand, may distort reality - sometimes intentionally - to influence decision-making in a particular direction. This can be especially problematic in agriculture, where farmers rely on data to determine which crops to plant, how to allocate resources, and how to maximize yield while minimizing environmental impact.

## Data visualization scenarios

The main content in this activity occurs days 2–4 with students using data to analyze a scenario to provide information to a farmer. Each scenario covers a different topic. An expanded background section for teachers follows for each scenario.

**Scenario #1: Finding the right fertilizer rate**

Fertilizers play a crucial role in modern agriculture by supplying essential nutrients like nitrogen, phosphorus, and potassium that helps crops grow efficiently. However, excessive fertilizer use can lead to nutrient runoff, water pollution, and soil degradation. Farmers must carefully balance fertilizer application to maximize crop yields while minimizing environmental impacts. In this scenario, students will analyze fertilizer application rates and crop yield to determine the optimal amount of fertilizer needed for sustainable farming. This scenario is suitable for all levels of students.

**Scenario #2: Plant density**
Plant density has a major impact on final crop yield. If soybeans are planted too densely, they compete for sunlight, water, and nutrients, reducing overall production. If they are planted too sparsely, farmers may not maximize land use. In this scenario, students analyze seeding rate and row spacing to determine the best planting strategy for maximizing soybean yield. This scenario is appropriate for all levels of students.

**Scenario #3: Finding the right animal to farm**
Farmers raising livestock must consider several factors when deciding which animals to raise, including feed efficiency, space requirements, etc. Some animals, like cows and pigs, require large amounts of feed. Other animals, like chickens and sheep, require less and may be more cost effective. Additionally, certain livestock provide multiple products which can make them more profitable. In this scenario, students analyze a variety of factors to determine which livestock option is best for the farm. This scenario is appropriate for all levels of students.

**Scenario #4: Seasonal ice cream sales and dairy farm milk production**
Dairy farms experience seasonal variations in milk production due to changes in temperature, feed availability, and cow physiology. Cows tend to produce more milk in cooler temperatures and may experience heat stress in warmer months reducing milk output. At the same time, consumer demand for dairy products such as ice cream increases in warm months. This scenario helps students analyze climate-driven production patterns and how farmers can mitigate heat stress using various methods such as cooling systems. This scenario is appropriate for all levels of students.

**Scenario #5: Water quality and sustainable fisheries**
Water is a critical resource for agriculture and aquaculture, but its quality can be impacted by pollution, runoff, and industrial activity. In this scenario, students examine a fishery facing declining fish populations due to changes in water quality - possibly caused by pollution from a nearby paper mill. This scenario is appropriate for all levels of students; however, students will be comparing and contrasting multiple graphs from a variety of variables which may impact some student’s abilities to accurately understand data.

**Scenario #6: Biotechnology and genetically modified crops**
Genetically modified organisms (GMOs) have transformed agriculture by enhancing crop resilience, increasing yields, and reducing pesticide use. Despite these benefits, GMOs remain controversial due to consumer perception and regulatory concerns. In this scenario, students explore public sentiment toward GMOs, analyze sales data, and evaluate whether consumer attitudes align with actual market trends. This scenario is appropriate for advanced students since additional research is required other than data presented on the student sheet.

**Scenario #7: Biofuels and sustainable energy**
Biofuels, such as ethanol and biodiesel, are renewable alternatives to gasoline and diesel made from corn, sugarcane, soybeans, and other plant materials. While biofuels offer reduced greenhouse gas emissions, they also have lower energy density which means that vehicles and farm equipment require more fuel per mile as compared to traditional fuels. In this scenario, students will evaluate whether a farmer should transition farming equipment to biofuels by analyzing energy density, fuel efficiency, cost per gallon and environmental impact to make an informed recommendation. This scenario is appropriate for all levels of students in heterogeneous groupings.

**Scenario #8: Cow nutrition and milk production**

In order to maintain a high level of production, lactating dairy cows, those actively producing milk, need a complete and balanced diet that meets their nutrient requirements for body maintenance, lactation, growth, and pregnancy. The most common way dairy farmers/nutritionists achieve this is through a total mixed ration (TMR). A TMR is a mixture of forages (e.g., hay and corn silage), concentrated feeds of protein (e.g., soybean meal and distiller's grains), and additional supplements (e.g., vitamins and minerals), which is balanced to meet the specific needs of each unique dairy herd. The goal of a total mixed ration is to provide a complete and consistent diet in each bite. When done correctly, these balanced bites support the rumen environment, allowing rumen microbes to turn "trash" (feed ingredients not fit for human consumption) into "treasure" (milk and other dairy products). A lactating cow requires increased levels of energy (carbohydrates and fats), in the form of an energy concentrate, and protein in order to sustain their body weight, level of milk production, and pregnancy/calf development. Lactating dairy cows will also eat much more than non-lactating cows, consuming 3.5–4.5% of their body weight daily, while non-lactating cows will consume only 2–3% of their body weight.

## Prior knowledge

Students should be familiar with different types of graphs and their unique characteristics:

- **Line graph:** shows change over time
- **Scatter plot:** establishes a relationship between two measurements
- **Histogram:** compares total amounts to each other
- **Circle graph (pie chart):** illustrates the relative size of the parts of a whole

For this particular lesson, students should have some sense about how graphs can be misleading. This is included on the student sheet for day 1.

| **Misleading technique** | **Description** | **Example in agriculture** |
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| Truncated y-axis | The y-axis does not start at zero. This can exaggerate differences between data points. | A fertilizer company may show crop growth with and without their product, but the y-axis makes the increase seem more dramatic than it actually is. |
| Inconsistent scaling | The x-axis or y-axis intervals are uneven. This can make data appear more or less significant than it actually is. | A graph comparing drought years may space out wet years disproportionately, making it look like droughts are occurring more frequently. |
| Cherry-picked data | Only a select portion of the data is shown. This can lead to ignoring information that may contradict a claim or provide only one portion of evidence for an explanation. | A seed company may present crop yields from only one successful season instead of showing a multi-year average. |
| Misleading pie charts | Pie chart slices are manipulated (either by size or by excluding categories). This can make one variable seem dominant. | A market report might exclude certain competitors in a pricing comparison, making one company appear to control a larger portion of the market. |

| Misleading technique | Description | Example in agriculture |
|---|---|---|
| Overuse of 3D effects | 3D graphs distort proportions. This makes some bars or slices appear larger than they actually are. | A dairy industry report might use 3D bars to make milk production increases seem larger than they are. |
| Cumulative graphs without clarification | A line graph showing cumulative data instead of yearly changes. This can create the illusion of constant increases. | A report on pesticide usage might show a growing line over several years, but it does not indicate if usage is leveling off or declining in recent years because of the cumulative effect of addition. |

Note: This is not a comprehensive listing of ways that data visualizations can be manipulated.

## Suggested timing

Activity: 3–4 class periods (45 minutes each)

## Materials

- Printed graphs for gallery walk of graphs
- Access to graphing programs such as Excel or Google Sheets
- Access to PowerPoint or Google Slides
- Internet access
- If the teacher chooses to complete this activity on paper rather than electronically, students will need graphing paper, straight edge/rule, and colored writing utensils (optional)

## Teacher preparation

To prepare for this lesson, the teacher should collect examples of graphs (both "fair" and "misleading") for students to examine during their gallery walk. In this gallery walk, students should analyze the graph to determine if it is fair or misleading. Then, students should provide evidence for their analysis. It is recommended that the teacher choose 10–15 graphs to display and students work in partners to encourage scientific discussion.

There are many misleading graphs that can be found after a quick online search. Some examples of misleading graphs are included as a separate document with this lesson.

## Procedure

### Day 1: Introduction to data visualization and gallery walk

1. Teacher mini-lesson (15 min.)
    a. Explain how data visualizations influence decision-making in agriculture.
    b. Show an example of a "fair" graph and a "misleading" graph and discuss common manipulation techniques.
    c. Engage students by asking *"Why might someone want to mislead with data? How can this affect farmers?"*
2. Gallery walk (25 min.)
    a. Set up stations around the room with different graphs: some fair, some misleading.
    b. Students rotate through each station, analyzing the graph using their student sheet to determine if the graph is fair or misleading and justifying their answer with evidence.

3. Class discussion (10 min.)
    a. Debrief: Discuss what made some graphs misleading and why it's important for farmers to analyze data critically.
    b. Introduce the idea that students will now act as data analysts to help farmers make decisions.

## Day 2: Scenario introduction and data analysis

1. Introduce activity (5 min.)
    a. Review basics of yesterday's lesson.
    b. Set the stage: discuss the implications of data driven farming with students.
2. Assign scenarios (5 min.)
    a. Tell students that they are now the data analyst assisting a local farmer with a very important decision.
    b. Divide students into groups based on eight scenario themes: see backgrounds and info above.
    c. Each group receives background information, a farmer's question, and a data set.
3. Group research and data analysis (35 min.)
    a. Students read and discuss their scenario.
    b. Students examine the provided dataset, identifying patterns or trends.
4. Exit ticket (5 min.)
    a. Each group writes down:
        - One interesting trend they noticed in their data
        - One question they still have

## Day 3: Data visualization and presentation prep

Students work on day 3 to complete their research, data visualization, and preparation for their presentation.

## Day 4: Presentation and class discussion

1. Group presentations (30 min)
    a. Each group presents their three-slide recommendation to the class.
    b. Classmates act as farmers, asking critical questions about the data.
2. Reflection and discussion (15 min)
    a. Pose the following question to the "farmers": *"How did data shape your recommendations? What challenges did you face in making fair graphs? How do misleading graphs impact real-world agricultural decisions?"*
3. Exit ticket (5 min.)
    a. Students answer:
        - What was the most surprising thing you learned about data in agriculture?
        - How can you apply these skills to real-world decision-making?

## Differentiation

Other ways to connect with students with various needs:

- **Local community:** In order to help students understand the role of data driven farming, a local farmer could be invited to the class as a guest speaker. If a guest speaker is unable to come to the classroom, local agricultural data could be used to make findings more relevant.
- **Students with special needs (language/reading/auditory/visual):** For students with special needs, visual supports could be provided as color-coded graphing templates, enlarged graphs, and pre-highlighted key data points. Graphic organizers could also be used to provide a step-by-step analysis chart for students to organize their observations.
- **Extra support:** When mathematical concepts are brought into the science classrooms, students sometimes struggle with the idea that math is an integral part of science. Introducing graphing techniques such as variable placement and the use of graphing software could provide extra support for all students prior to the lesson.
- **Extensions:** For advanced learners, students could investigate an agricultural issue of their choice, collect or find relevant data, and present their findings in a report rather than using the scenarios provided.

## Assessments

### Rubric for assessment

| Skill | Developing | Satisfactory | Exemplary |
|---|---|---|---|
| **Identifying fair and misleading graphs (day 1)** | Struggles to differentiate between fair and misleading graphs; explanations lack clarity or depth | Identifies fair and misleading graphs correctly most of the time; provides basic reasoning for decisions | Accurately analyzes and explains how data is manipulated in misleading graphs; uses specific examples and clear justifications |
| **Creating a fair and accurate data visualization (days 2–3)** | Data is graphed but may contain errors in scale, axis labels, or representation; may not clearly communicate findings | Creates an appropriate graph that accurately represents the data with correct labels and scaling | Produces a precise and well-labeled graph that effectively highlights key trends and relationships in the data |
| **Using evidence to support a claim (days 2–3)** | Provides a claim but lacks strong evidence from the dataset; reasoning is unclear or incomplete | Uses data as evidence to support a claim with some reasoning buy may lack depth | Uses data effectively to construct a clear, evidence based argument with well-reasoning justification |
| **Collaborating and engaging in scientific discourse** | Participates minimally in group discussions and struggles to contribute meaningfully | Works collaboratively to analyze data and construct a presentation, engaging in discussion with some insights | Actively contributes ideas, helps guide group decisions, and engages in critical discourses with classmates |

## Rubric for self-assessment

| Skill | Yes | No | Unsure |
|---|---|---|---|
| I can identify differences between fair and misleading graphs and explain why a graph may be misleading. | | | |
| I accurately created a graph that best represents the data from my scenario. | | | |
| I used evidence to support my claim and recommendation to the farmer. | | | |
| I communicated my findings clearly in my group presentation. | | | |
| I worked effectively with my group to analyze data and prepare our presentation. | | | |
| I can explain how misleading data could negatively impact real-world agricultural decisions. | | | |