# Past-paper walk-through

## Impacts of Agricultural Practices ▪ 5.4

eXercise

# Questions in this set

- 2026 Q2
- 2024 Set 1 Q2
- 2024 Set 2 Q1
- 2024 Set 2 Q2
- 2023 Set 1 Q1
- 2023 Set 2 Q3
- 2022 Set 1 Q1
- 2022 Set 2 Q1
- 2022 Set 2 Q2
- 2021 Set 2 Q1

# Questions in this set

- 2016 Q4
- 2015 Q1

# Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

# Question 2

2026 ▪ Q2

The following information applies to parts A, B, C, D, E, F, and G.
The following graph shows the number of quadrillion British thermal units (BTUs) that were consumed in the United States using five different energy sources from 1950 to 2020.

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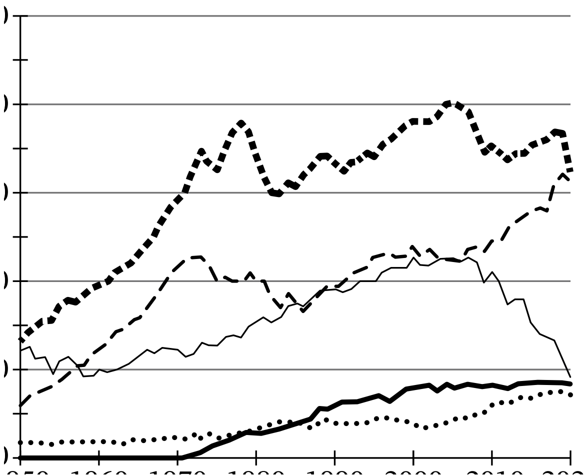
The following information applies to parts H and I.

Researchers studied an aquatic ecosystem near an area of land that had been converted to agricultural use. They reported an increase in nutrients, such as nitrates and phosphates, in the water.

**2.** Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

**(a) Identify** one renewable energy source that is used to generate electricity.

# Question 2



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**2.** Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

**(b)** Based on the data in the graph, **identify** the energy source that had the highest consumption in 2010.

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**2.** Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

**(c)** Based on the data in the graph, **describe** the pattern in the energy consumption from coal in the United States from 1960 to 2020.

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**2.** Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

**(d)** Based on the data in the graph and your knowledge of energy consumption, **explain** one likely reason why the use of coal for energy changed between 2010 and 2020.

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**2.** Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

**(e) Explain** how fossil fuels are used to generate electricity.

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2026 ▪ Q2

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**2.** Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

**(f)** In addition to fossil fuels, nuclear power can be used to generate electricity. **Identify** one negative impact associated with nuclear energy.

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**2.** Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

**(g)** Fossil fuel combustion leads to ocean warming. **Describe** one environmental problem other than coral bleaching that is associated with warming oceans.

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**2.** Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

**(h) Explain** how an increase in nutrients, such as nitrates and phosphates, can negatively affect an aquatic ecosystem.

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**2.** Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

**(ii) Propose** a realistic solution that would reduce nutrient pollution of waterways, while still allowing cultivation of crops.

**(iii) Justify** the solution proposed in part **I** (i) by explaining one potential advantage other than reducing nutrient runoff.

# Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg $CO_2$-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared ($m^2$).
**Global Warming Potential and Land Use from Animal Protein Production**
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg $CO_2$-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms ( 10), Chicken ( 27), Pork ( 37), Beef ( 120).]

# Question 2

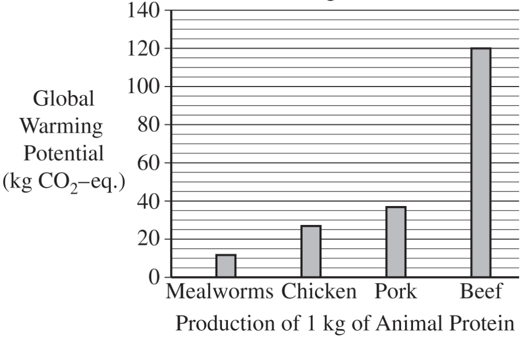
[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use ($m^2$)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms ( 18), Chicken ( 50), Pork ( 53), Beef ( 188).]

**(a)** Based on the data in the graphs, **identify** the amount of land required to produce 1 kilogram of chicken protein.

Mealworms, the larvae of the darkling beetle, consume grains and decaying plant material. Darkling beetles are an *r*-selected species, and the entire mealworm can be consumed by humans for protein.

# Question 2

Figure 1

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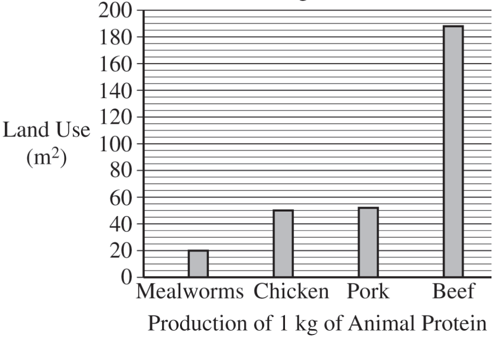

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# Question 2

**(b)** Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle.

# Question 2

2024 Set 1 ▪ Q2

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# Question 2

**(c) Explain** why the reproductive strategy of the darkling beetle is an advantage for using mealworms as an alternative protein source for the rapidly growing human population.

An individual's diet choices affect greenhouse gas emissions and land use.

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# Question 2

**(d)** Based on the data in the graphs, **explain** whether producing 1 kilogram of chicken protein or 1 kilogram of pork protein would cause less environmental damage.
Cattle emit methane from fermentation in their digestive systems. The other animals do not emit methane.

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2024 Set 1 ▪ Q2

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# Question 2

**(e)** Based on the data in the graphs, **explain** why the production of 1 kilogram of beef protein has a different impact on global warming than the production of 1 kilogram of protein from any of the other animals studied would have.
Agricultural practices can have negative impacts on rivers and streams.

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2024 Set 1 ▪ Q2

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# Question 2

**(f) Describe** how water quality can be altered by cattle grazing that occurs near a stream or river.

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[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg $CO_2$-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms ( 10), Chicken ( 27), Pork ( 37), Beef ( 120).]
[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use ($m^2$)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms ( 18), Chicken ( 50), Pork ( 53), Beef ( 188).]

# Question 2

**(g) Propose** a solution to reduce the negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze.

# Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg $CO_2$-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared ($m^2$).
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# Question 2

**(h)** Crop production can cause soil erosion. **Describe** a sustainable agricultural practice used to reduce soil erosion.

# Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg $CO_2$-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared ($m^2$).

**Global Warming Potential and Land Use from Animal Protein Production**

[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg $CO_2$-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms ( 10), Chicken ( 27), Pork ( 37), Beef ( 120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use ($m^2$)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms ( 18), Chicken ( 50), Pork ( 53), Beef ( 188).]

# Question 2

**(i) Justify** the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion.

# Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg $CO_2$-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared ($m^2$).
**Global Warming Potential and Land Use from Animal Protein Production**
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# Question 2

**(j)** Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change.

# Solution 2

## (a)

**Mark scheme**

- 50 $m^2$ of land is required to produce 1 kilogram of chicken protein (read from the graph).

# Solution 2

**(b)**

**Mark scheme**

- The darkling beetle exhibits a Type III survivorship curve (high mortality early in life, few survivors reach old age — consistent with an r-selected species).

# Solution 2

## (c)

### Mark scheme

- Darkling beetles are r-selected and reproduce quickly with many offspring, which allows a large amount of protein (mealworm biomass) to be produced in a short period of time — an advantage for feeding a rapidly growing human population.

# Solution 2

**(d)**

**Mark scheme**

- Producing 1 kg of chicken protein causes less environmental damage than producing 1 kg of pork protein: chicken production has a lower global warming potential (releases less greenhouse gas) than pork, and/or chicken has lower land use than pork, so it causes less deforestation/habitat destruction/soil erosion/fossil fuel use.

# Solution 2

**(e)**

**Mark scheme**

- Beef production has a larger impact on global warming than the other animals studied because cattle emit methane from digestive (enteric) fermentation, and methane is a greenhouse gas with a high global warming potential; beef also requires much more land use, which causes loss of forests/habitat/grasslands and releases stored CO2 (reducing carbon storage).

# Solution 2

## (f)

**Mark scheme**

- Cattle grazing near a stream or river can alter water quality by: causing erosion that increases sedimentation/turbidity in the water; adding nutrients (nitrogen/phosphorus) to waterways via feces; and/or contaminating waterways with bacteria from feces.

# Solution 2

**(g)**

**Mark scheme**

- A solution that reduces waterway damage while still allowing grazing: practice rotational grazing (alternate grazing parcels so land can recover); reduce dietary reliance on meat/beef; fence/barricade the riparian zone to keep cattle out of the waterway; or provide alternative water sources for the cattle away from the stream.

# Solution 2

**(h)**

**Mark scheme**

- A sustainable agricultural practice to reduce soil erosion: switch crops to perennial plants; plant crops on terraces; implement contour plowing/farming; or use no-till farming/cover crops.

# Solution 2

## (i)

**Mark scheme**

- Justify the practice named in part (h) with an advantage beyond reduced erosion. Matching the scoring table: perennial crops or no-till/cover crops $\rightarrow$ reduce fossil fuel use, reduce farming costs, increase/maintain soil carbon storage, and preserve soil habitat for organisms (cover crops can also serve as green manure); terracing or contour plowing $\rightarrow$ allows otherwise-too-steep areas to be farmed and increases groundwater absorption (terracing also lets sediment/contaminants settle out behind the ridge, further reducing runoff).

# Solution 2

**(j)**

**Mark scheme**

- Climate change could negatively affect crop production/yields through: increased drought; increased flooding; increased insect infestation due to warmer temperatures; increased temperature generally; changes in seasonal rain patterns; expansion of the geographic range of invasive pests/species; or climate conditions moving outside crops' range of tolerance.

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.
[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing "Bedrock" (dotted pattern) and "Soil" (solid gray). A horizontal arrow below labeled "Time" points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

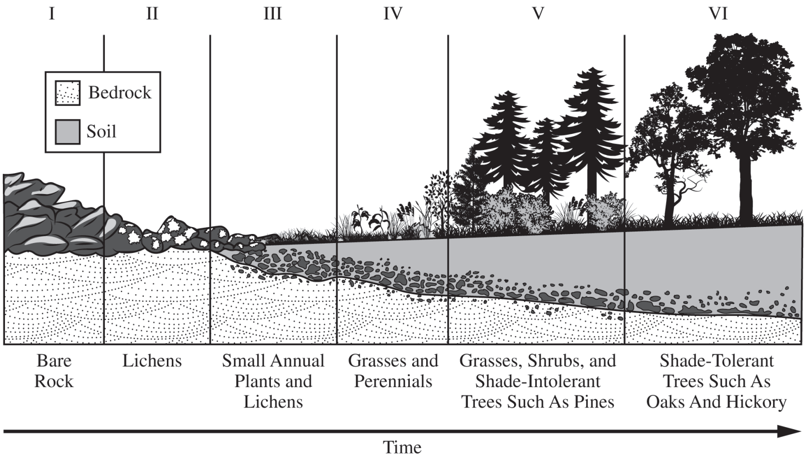
- Stage I: Bare Rock

# Question 1

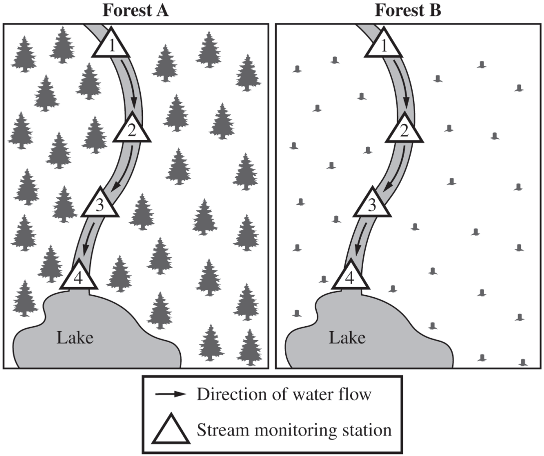
- Stage II: Lichens
- Stage III: Small Annual Plants and Lichens
- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(a)** Identify the ecological change over time illustrated in the diagram.

# Question 1


I
II
III
IV
V
VI
Bedrock
Soil
Bare Rock
Lichens
Small Annual Plants and Lichens
Grasses and Perennials
Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
Shade-Tolerant Trees Such As Oaks And Hickory
Time

# Question 1


Forest A
Forest B
1
2
3
4
1
2
3
4
Lake
Lake
Direction of water flow
Stream monitoring station

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.

[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing "Bedrock" (dotted pattern) and "Soil" (solid gray). A horizontal arrow below labeled "Time" points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

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# Question 1

- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(b)** Identify the stage in which pioneer species first appear.

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.

[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing "Bedrock" (dotted pattern) and "Soil" (solid gray). A horizontal arrow below labeled "Time" points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

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# Question 1

- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(c)** Describe how soil forms from stage II to stage III.

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.
[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing "Bedrock" (dotted pattern) and "Soil" (solid gray). A horizontal arrow below labeled "Time" points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

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# Question 1

- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(d)** Identify a cultural ecosystem service that may be provided by a mature forest.

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.
[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing "Bedrock" (dotted pattern) and "Soil" (solid gray). A horizontal arrow below labeled "Time" points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

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# Question 1

- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(e)** Researchers are interested in investigating the effect of the removal of trees on the water quality of nearby waterways. To conduct their experiment, the researchers locate two identical forest watersheds, both with a river running through them. Forest A is an intact forest and forest B is a clear-cut forest. Four stream monitoring stations are set up in each forest study area. Each station monitors a variety of water quality indicators, including water temperature, at various locations along the river. The experimental setup is shown in the following diagrams. The arrows shown in the rivers represent the direction of water flow. The triangles in the river show the location of the stream monitoring stations.

# Question 1

[Diagram: Two side-by-side maps labeled “Forest A” and “Forest B”, each showing a river flowing from the top of the map down to a “Lake” at the bottom, with 4 numbered triangular stream monitoring stations (labeled 1 at the top near where the river enters, 2, 3, and 4 near the lake) placed along the river’s path. Arrows along the river indicate the direction of water flow, flowing downward toward the lake. Forest A is densely covered with many tree symbols (an intact forest). Forest B has only a few scattered tree symbols, showing that most trees have been cleared (a clear-cut forest). A legend below both maps indicates: an arrow icon = “Direction of water flow”; a triangle icon = “Stream monitoring station”.]
Identify a testable hypothesis being investigated by the researchers.

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.
[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing "Bedrock" (dotted pattern) and "Soil" (solid gray). A horizontal arrow below labeled "Time" points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

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# Question 1

- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(f)** Identify the independent variable in the experiment.

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.
[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing "Bedrock" (dotted pattern) and "Soil" (solid gray). A horizontal arrow below labeled "Time" points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

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# Question 1

- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(g)** Describe the purpose of forest A in the experiment.

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.
[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing "Bedrock" (dotted pattern) and "Soil" (solid gray). A horizontal arrow below labeled "Time" points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

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# Question 1

- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(h)** Explain why the water temperature might change because of clear-cutting trees in forest B.

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.
[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing “Bedrock” (dotted pattern) and “Soil” (solid gray). A horizontal arrow below labeled “Time” points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

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# Question 1

- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(i)** After the experiment was completed, land developers constructed a golf course in the clear-cut area of forest B. To prepare the land, developers removed any remaining stumps and newly grown trees and began planting and fertilizing new grass. The researchers are interested in the effect the golf course may have on the water quality of the river. To monitor the river in forest B, the researchers repeated the experiment once the golf course had been constructed.
Explain why an indicator of water quality other than temperature could be altered by the golf course in forest B.

# Question 1

2024 Set 2 ▪ Q1

The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.
[Diagram: A cross-section showing ecological succession over time, divided into six stages labeled with roman numerals I through VI, with a key showing "Bedrock" (dotted pattern) and "Soil" (solid gray). A horizontal arrow below labeled "Time" points left to right. The cross-section shows bedrock and soil layers progressively deepening from left (mostly exposed bedrock) to right (thick soil layer) as vegetation on top becomes progressively taller and denser. The six stages are labeled below the diagram:

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- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

**(j)** Explain how the aquatic organisms living in the lake illustrated in the diagram of forest B are likely to be affected by the new golf course.

# Solution 1

## (a)

**Mark scheme**

- The diagram shows primary succession – the stepwise development of an ecosystem starting on bare rock/parent material with no pre-existing soil, progressing through stages to a mature community. Full credit for identifying 'primary succession.'

# Solution 1

## (b)

**Mark scheme**

- Pioneer species first appear in Stage II (labeled '2' in the diagram) – the stage where organisms like lichens, algae, or fungi first colonize the bare rock. Full credit for identifying stage II/2.

# Solution 1

## (c)

**Mark scheme**

- Soil forms from stage II to stage III through weathering and biological activity. Accept any one of: (1) wind/rain/weather erodes the rock/parent material; (2) wind/rain breaks rocks down into smaller particles; (3) pioneer species (lichens/algae/fungi) die off, adding small amounts of organic material to the forming soil; (4) pioneer species (lichens/algae/fungi) help break down the rock. Full credit for any one mechanism.

# Solution 1

**(d)**

**Mark scheme**

- A cultural ecosystem service from a mature forest: any one of recreation, aesthetic enjoyment, spiritual use, ecotourism, or education. Full credit for naming one such non-material benefit.

# Solution 1

## (e)

### Mark scheme

- A testable hypothesis for the experiment, e.g.: removal of trees/clear-cutting will lead to an increase/decrease in a water-quality indicator (temperature, turbidity, or dissolved oxygen) compared with the intact forest, OR the null form – clear-cutting will have no effect on water quality; equivalently, water quality will/will not change between stations. Full credit for any hypothesis stating a predicted increase/decrease/no-change relationship between clear-cutting (or station location) and a water-quality indicator.

# Solution 1

## (f)

**Mark scheme**

- Independent variable: presence or absence of clear-cutting (intact forest A vs. clear-cut forest B), equivalently the intact-or-clearcut status of the forest or the location of the stream monitoring stations. Full credit for identifying this manipulated/comparison variable.

# Solution 1

## (g)

### Mark scheme

- Forest A (the intact forest) serves as the control – it lets researchers compare water quality (temperature/turbidity) in the clear-cut area (forest B) against an intact, unaltered baseline. Full credit for describing forest A's role as the control/comparison for forest B.

# Solution 1

## (h)

**Mark scheme**

- Water temperature in forest B is likely to increase after clear-cutting. Accept any one mechanism: (1) fewer/no trees to block sunlight from reaching the water, so it warms more; (2) additional sediment from erosion affects the water; (3) more direct sunlight reaches the water surface without the tree canopy. Full credit for any one causal explanation linking tree removal to warmer water.

# Solution 1

**(i)**

## Mark scheme

- A water-quality indicator besides temperature (e.g. dissolved oxygen, turbidity, or nutrients) could be altered by the golf course. Accept any one: (1) dissolved oxygen could decrease because fertilizer runoff causes algal blooms/eutrophication; (2) sedimentation/turbidity could decrease because grass reduces erosion compared with bare clear-cut land; (3) nitrates/phosphates could increase due to fertilizer runoff, driving algal growth/bloom. Full credit for any one linked mechanism.

# Solution 1

## (j)

### Mark scheme

- Effect on aquatic organisms in the forest B lake from the new golf course. Accept any one: (1) organisms die off from lack of oxygen caused by decomposition of algae/eutrophication (from fertilizer runoff); (2) organisms survive at a higher rate because less sediment clogs their gills (grass reduces erosion versus clear-cut land); (3) organisms die off due to increased toxicity from pesticide runoff. Full credit for any one plausible, correctly reasoned effect.

# Question 2

2024 Set 2 ▪ Q2

The following graph shows how global uses of habitable land have changed since 1700. [Bar chart titled "Land Use Changes on Earth, 1700-2018". Y-axis: "Percentage of Habitable Land" from 0% to 100% in increments of 20%. X-axis: "Year", with stacked bars shown for 1700, 1800, 1900, 1950, 2000, and 2018. Each bar is stacked (from bottom to top) with five categories per the legend: Forest (light gray), Crops (dark gray), Grazing (diagonal hatched pattern), Wild grasslands (white), Built-up land (black, thin sliver at the very top). Approximate stacked values read from the graph:

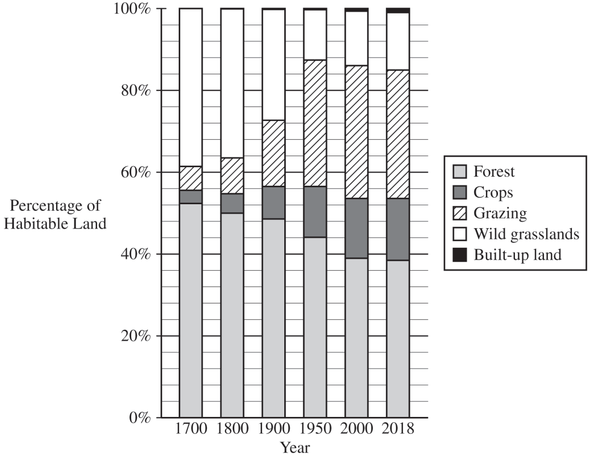
- 1700: Forest $\approx$ 53%, Crops $\approx$ 2%, Grazing $\approx$ 6%, Wild grasslands $\approx$ 38% (top reaches 100%), Built-up land negligible.
- 1800: Forest $\approx$ 51%, Crops $\approx$ 4%, Grazing $\approx$ 9%, Wild grasslands $\approx$ 36%, Built-up land negligible.

# Question 2

- 1900: Forest $\approx$ 49%, Crops $\approx$ 8%, Grazing $\approx$ 16%, Wild grasslands $\approx$ 27%, Built-up land negligible.
- 1950: Forest $\approx$ 45%, Crops $\approx$ 12%, Grazing $\approx$ 31%, Wild grasslands $\approx$ 12%, Built-up land $\approx$ small sliver.
- 2000: Forest $\approx$ 39%, Crops $\approx$ 15%, Grazing $\approx$ 32%, Wild grasslands $\approx$ 13%, Built-up land $\approx$ small sliver.
- 2018: Forest $\approx$ 38%, Crops $\approx$ 15%, Grazing $\approx$ 33%, Wild grasslands $\approx$ 13%, Built-up land $\approx$ small sliver.]

**(a)** Based on the data in the graph, identify the year with the highest percentage of forest.

# Question 2


100%
80%
60%
40%
20%
0%
Percentage of Habitable Land
1700
1800
1900
1950
2000
2018
Year
Forest
Crops
Grazing
Wild grasslands
Built-up land

# Question 2

2024 Set 2 ▪ Q2

The following graph shows how global uses of habitable land have changed since 1700.
[Bar chart titled "Land Use Changes on Earth, 1700-2018". Y-axis: "Percentage of Habitable Land" from 0% to 100% in increments of 20%. X-axis: "Year", with stacked bars shown for 1700, 1800, 1900, 1950, 2000, and 2018. Each bar is stacked (from bottom to top) with five categories per the legend: Forest (light gray), Crops (dark gray), Grazing (diagonal hatched pattern), Wild grasslands (white), Built-up land (black, thin sliver at the very top).
Approximate stacked values read from the graph:

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- 2018: Forest $\approx$ 38%, Crops $\approx$ 15%, Grazing $\approx$ 33%, Wild grasslands $\approx$ 13%, Built-up land $\approx$ small sliver.]

**(b)** Based on the data in the graph, describe the relationship between the land use changes in the wild grasslands and grazing from 1700 to 1950.

# Question 2

2024 Set 2 ▪ Q2

The following graph shows how global uses of habitable land have changed since 1700. [Bar chart titled "Land Use Changes on Earth, 1700-2018". Y-axis: "Percentage of Habitable Land" from 0% to 100% in increments of 20%. X-axis: "Year", with stacked bars shown for 1700, 1800, 1900, 1950, 2000, and 2018. Each bar is stacked (from bottom to top) with five categories per the legend: Forest (light gray), Crops (dark gray), Grazing (diagonal hatched pattern), Wild grasslands (white), Built-up land (black, thin sliver at the very top). Approximate stacked values read from the graph:

- 1700: Forest ≈ 53%, Crops ≈ 2%, Grazing ≈ 6%, Wild grasslands ≈ 38% (top reaches 100%), Built-up land negligible.
- 1800: Forest ≈ 51%, Crops ≈ 4%, Grazing ≈ 9%, Wild grasslands ≈ 36%, Built-up land negligible.

# Question 2

- 1900: Forest $\approx$ 49%, Crops $\approx$ 8%, Grazing $\approx$ 16%, Wild grasslands $\approx$ 27%, Built-up land negligible.
- 1950: Forest $\approx$ 45%, Crops $\approx$ 12%, Grazing $\approx$ 31%, Wild grasslands $\approx$ 12%, Built-up land $\approx$ small sliver.
- 2000: Forest $\approx$ 39%, Crops $\approx$ 15%, Grazing $\approx$ 32%, Wild grasslands $\approx$ 13%, Built-up land $\approx$ small sliver.
- 2018: Forest $\approx$ 38%, Crops $\approx$ 15%, Grazing $\approx$ 33%, Wild grasslands $\approx$ 13%, Built-up land $\approx$ small sliver.]

**(c)** Identify an environmental problem associated with overgrazing by livestock.

# Question 2

2024 Set 2 ▪ Q2

The following graph shows how global uses of habitable land have changed since 1700. [Bar chart titled "Land Use Changes on Earth, 1700-2018". Y-axis: "Percentage of Habitable Land" from 0% to 100% in increments of 20%. X-axis: "Year", with stacked bars shown for 1700, 1800, 1900, 1950, 2000, and 2018. Each bar is stacked (from bottom to top) with five categories per the legend: Forest (light gray), Crops (dark gray), Grazing (diagonal hatched pattern), Wild grasslands (white), Built-up land (black, thin sliver at the very top). Approximate stacked values read from the graph:

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# Question 2

- 1900: Forest $\approx$ 49%, Crops $\approx$ 8%, Grazing $\approx$ 16%, Wild grasslands $\approx$ 27%, Built-up land negligible.
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**(d)** A student hypothesized that the change in the percentage of forest from 1700 to 2018 has decreased atmospheric carbon dioxide concentrations. Explain whether the hypothesis is supported or refuted based on the data in the graph.

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2024 Set 2 ▪ Q2

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**(e)** Urban environments have accounted for an increasing percentage of land use within the last few decades.
Describe a water-related environmental problem associated with urbanization.

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2024 Set 2 ▪ Q2

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**(f)** Describe a potential response to mitigate the environmental problem identified in part (e).

# Question 2

2024 Set 2 ▪ Q2

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# Question 2

**(g)** Farmers who own large sections of cropland notice that bobcats, a medium-sized predatory forest cat, were present many years ago but are now virtually absent in the area. Instead, smaller mammal species now inhabit the area. Over time, the farmers have cleared nearly all of the forest on their property and converted it to farmland. Explain why there are fewer bobcats present on the farmland now compared to several decades ago.

# Question 2

2024 Set 2 ▪ Q2

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# Question 2

**(h)** The small mammal species are considered pests by the farmers. The farmers partner with a conservation group to increase the number of bobcats in the area. As a solution, the conservation group will introduce bobcats onto the few isolated patches of the original forested habitat left in the area. They can introduce only a small number of bobcats in each patch.

Describe a disadvantage of introducing only a small population of bobcats.

# Question 2

2024 Set 2 ▪ Q2

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**(i)** Propose a solution to improve the chances that the bobcat reintroductions will be successful in reestablishing wild populations.

# Question 2

2024 Set 2 ▪ Q2

The following graph shows how global uses of habitable land have changed since 1700. [Bar chart titled "Land Use Changes on Earth, 1700-2018". Y-axis: "Percentage of Habitable Land" from 0% to 100% in increments of 20%. X-axis: "Year", with stacked bars shown for 1700, 1800, 1900, 1950, 2000, and 2018. Each bar is stacked (from bottom to top) with five categories per the legend: Forest (light gray), Crops (dark gray), Grazing (diagonal hatched pattern), Wild grasslands (white), Built-up land (black, thin sliver at the very top). Approximate stacked values read from the graph:

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**(j)** Justify the solution proposed in part (i) by describing an additional advantage, other than reestablishing the bobcat population near the farms.

# Solution 2

## (a)

### Mark scheme

- The year with the highest percentage of forest is 1700 (the earliest year shown, before land conversion to grazing/agriculture/urban use). Full credit for identifying 1700.

# Solution 2

**(b)**

**Mark scheme**

- From 1700 to 1950, the percentage/amount of wild grasslands decreased while the percentage/amount of grazing land increased – the two variables have an inverse relationship (as one goes down, the other goes up). Full credit for describing this inverse relationship.

# Solution 2

**(c)**

**Mark scheme**

- An environmental problem from overgrazing by livestock: any one of loss of vegetation, soil erosion, desertification, sedimentation/turbidity in waterways, or soil compaction. Full credit for naming one such problem.

# Solution 2

**(d)**

**Mark scheme**

- The hypothesis is refuted/disproved/not supported. The percentage of forest has decreased from 1700 to 2018, so the amount of photosynthesis/carbon sequestration by forests has also decreased – this would tend to increase, not decrease, atmospheric CO2, contradicting the hypothesis. Full credit for concluding 'refuted' with reasoning tied to the graph.

# Solution 2

**(e)**

**Mark scheme**

- A water-related environmental problem from urbanization: any one of (1) increased runoff/flooding because urban areas have more impermeable surfaces; (2) decreased groundwater/saltwater intrusion because urban areas have many people and groundwater is overused; (3) increased water pollution because precipitation/runoff carries contaminants/pollutants/waste; (4) destruction of aquatic habitats from increased development/land-use change. Full credit for describing one such problem.

# Solution 2

## (f) Mark scheme

- A potential mitigation matched to the problem named in part (e): if increased runoff/flooding – use permeable road/parking materials, set aside green spaces/parks/conservation areas, or construct green roofs/rain gardens/stormwater retention ponds; if decreased groundwater/saltwater intrusion – permeable materials, groundwater conservation/management plans, protected recharge zones, or green roofs/rain gardens/retention ponds; if increased water pollution – encourage walking/biking, reduce home pesticide/fertilizer use, reduce road salt/de-icing chemical use, pick up trash/litter along waterways, or properly dispose of toxic chemicals; if destruction of aquatic habitats – create conservation

# Solution 2

areas/preserves/wetlands or restore degraded aquatic habitats. Full credit for any response that logically mitigates the problem identified in (e).

# Solution 2

**(g)**

**Mark scheme**

- Fewer bobcats are present on the farmland now because: (1) loss of forest habitat (cleared for farmland) has decreased resources such as food, shelter, mates, or migration routes; or (2) trapping/hunting has reduced the bobcat population. Full credit for either explanation.

# Solution 2

## (h)

### Mark scheme

- A disadvantage of introducing only a small bobcat population: any one of (1) lower genetic diversity; (2) genetic bottlenecks leading to inbreeding/passing on negative traits; (3) greater vulnerability to disease or disturbances like wildfire; (4) less effective control of small mammal/pest populations than a larger population; (5) lower likelihood of survival. Full credit for any one such disadvantage.

# Solution 2

## (i)

### Mark scheme

- A solution to improve reintroduction success: (1) increase connectivity/build habitat corridors so bobcats can safely mate, find food, and build dens; or (2) restore/reforest/preserve areas of bobcat habitat. Full credit for either proposal.

# Solution 2

## (j) Mark scheme

- An additional advantage of the proposed solution (beyond reestablishing bobcats), matched to the answer given in (i): if habitat corridors – they can be used by other species, increase biodiversity/population of other species, attract species beneficial to farmers (pest predators/pollinators), or reduce roadkill/vehicle collisions with wildlife; if restoring/reforesting/preserving habitat – restored habitat can be used by other species, restoration can increase biodiversity/improve air or water quality, or added trees improve aesthetic value, tourism, reduce erosion, or serve as a carbon sink. Full credit for any advantage consistent with the part (i) solution.

# Question 1

2023 Set 1 ▪ Q1

Researchers interested in sustainability developed three new varieties of genetically modified green beans designed to produce higher yields in arid regions. Four plots (A-D) were set up on a floodplain of a river to grow beans. Plots A, B, and C were each planted with seeds of different types of genetically modified strains of green beans. Plot D was planted with seeds of unmodified green beans. Each plot was given equal amounts of fertilizer, which contains phosphorus and nitrogen, and water and was irrigated using spray irrigation for one hour per day. Throughout the growing season, researchers measured the amount of green beans harvested within each plot. The plots with genetically modified beans had higher crop yields than the plot with unmodified beans.

**(a)** Identify the control group in this experiment.

# Question 1

2023 Set 1 ▪ Q1

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**(b)** Identify the scientific question for the investigation.

# Question 1

2023 Set 1 ▪ Q1

## Question 1

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# Question 1

**(c)** Researchers repeated the experiment by modifying the length of time for the spray irrigation to 20 minutes per day. Explain how the results of the experiment could be altered with this modification. Researchers also monitored the amount of sediment and fertilizer washing into the river from each plot in the original study. The soil temperature was also measured in each plot at the same depth and at the same time each day approximately 0.05 meters below the surface of the soil.

**Genetically Modified Green Bean Experimental Results**

| Plot | Sediment Runoff (mg/L) | Phosphorus Runoff (mg/L) | Nitrogen Runoff (mg/L) | Soil Temperature (°C) |
|---|---|---|---|---|
| A (Type 1 GMO beans) | 2.4 | 0.11 | 1.07 | 18.6 |
| B (Type 2 GMO beans) | 2.1 | 0.02 | 0.56 | 18.3 |
| C (Type 3 GMO beans) | 0.9 | 0.04 | 0.68 | 18.3 |
| D (Unmodified | 3.5 | 0.15 | 1.24 | 17.6 |

# Question 1

2023 Set 1 ▪ Q1

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**(d)** Based on the data in the table, identify the plot with the lowest soil temperature.

# Question 1

2023 Set 1 ▪ Q1

Researchers interested in sustainability developed three new varieties of genetically modified green beans designed to produce higher yields in arid regions. Four plots (A-D) were set up on a floodplain of a river to grow beans. Plots A, B, and C were each planted with seeds of different types of genetically modified strains of green beans. Plot D was planted with seeds of unmodified green beans. Each plot was given equal amounts of fertilizer, which contains phosphorus and nitrogen, and water and was irrigated using spray irrigation for one hour per day. Throughout the growing season, researchers measured the amount of green beans harvested within each plot. The plots with genetically modified beans had higher crop yields than the plot with unmodified beans.

**(e)** Describe how sediment runoff and fertilizer runoff compare between the unmodified green beans and the genetically modified green beans.

# Question 1

2023 Set 1 ▪ Q1

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**(f)** The Type 2 GMO beans in Plot B were developed to grow more quickly than the unmodified beans in Plot D. Researchers have hypothesized that the Type 2 beans would use fertilizer more completely than the other varieties. Based on the data in the

# Question 1

table and the experimental design, explain whether the researchers' hypothesis was supported or refuted.

# Question 1

2023 Set 1 ▪ Q1

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**(g)** Once the experiment was concluded, the researchers burned the plots to remove the crops that had been planted. After a few years, the researchers returned to the plots and observed a variety of plants, insects, and bird species living there.

# Question 1

Describe the ecological process that occurred on the plots after the crops were burned.

# Question 1

2023 Set 1 ▪ Q1

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**(h)** A survey indicated that one of the plots had twice the plant diversity that the other plots had. Over the next five years, the river occasionally flooded the plots, killing off many of the species that inhabited the plots.

# Question 1

After each flooding event, the plot with twice the plant diversity returned to its prior level of biodiversity more quickly than the other plots did. Explain why a community with more plant diversity will recover more quickly from the flooding.

# Question 1

2023 Set 1 ▪ Q1

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**(i)** After the last flooding event, a beetle not previously known in the area appeared in one of the plots with less plant diversity. Over a period of a few months, the new beetle population increased, whereas the existing beetle species in the plot had

# Question 1

declining populations. Explain why the new beetle species could be better able to successfully populate this plot than the existing beetle species could.

# Question 1

2023 Set 1 ▪ Q1

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**(j)** Describe one realistic method to prevent the new beetle from spreading beyond the experimental plot.

# Solution 1

## (a)

**Mark scheme**

- The control group is Plot D, the unmodified (non-GMO) green beans.

# Solution 1

## (b)

**Mark scheme**

- Any one of: Will genetically modified green beans have higher crop yields than unmodified green beans? / Is there a difference between the crop yields of genetically modified and unmodified green beans? / Does genetically modifying green beans affect crop yield?

# Solution 1

**(c)**

**Mark scheme**

- With only 20 minutes/day of spray irrigation (less water than the original setup), crop yield/number of green beans harvested would be lower in all plots. Alternatively: the genetically modified beans would stay similar in yield because they are drought-resistant/need less water, while the unmodified beans would decrease in yield because they receive less water than they need.

# Solution 1

**(d)**

**Mark scheme**

- Plot D (the unmodified green beans) has the lowest soil temperature, based on the data table.

# Solution 1

## (e)

### Mark scheme

- Both sediment runoff and fertilizer (phosphorus/nitrogen) runoff are lower with the genetically modified beans than with the unmodified beans (equivalently: both types of runoff are higher with the unmodified beans).

# Solution 1

## (f)

**Mark scheme**

- The hypothesis is supported. Any one justification: there is less fertilizer (phosphorus/nitrogen) in the runoff from Plot B, so the Type 2 GMO beans are absorbing/taking up more fertilizer; or there is more fertilizer in the runoff from Plot D, so the unmodified beans in Plot D are taking up less fertilizer; or the Plot B beans produced more beans given the same amount of fertilizer.

# Solution 1

**(g)**

**Mark scheme**

- Secondary succession occurred: fast-growing, early-successional (pioneer) organisms recolonized/returned to the soil after the fire (a major disturbance), since the soil itself was not destroyed.

# Solution 1

## (h)

**Mark scheme**

- Any one of: the higher-diversity plot has more species/organisms, so the flood harms a smaller proportion of the total species/organisms present; the higher-diversity plot has more connections between organisms (food-web links), so the flood disrupts a smaller percentage of those connections; or higher genetic diversity within species means more flood-tolerant individuals survive to repopulate.

# Solution 1

## (i)

**Mark scheme**

- Any one of: the new beetle is likely a generalist/r-selected species that can reproduce/spread quickly and outcompete the existing (native) beetle species; the flooding caused a natural disturbance to the existing community, eliminating predators/competitors and opening niches for the new/invasive beetle; low-diversity communities are more susceptible to disruption and recover poorly, allowing the new/nonnative beetle to invade; or the new beetle is an invasive species able to live outside its normal environment and threaten native species.

# Solution 1

## (j)

**Mark scheme**

- Any one realistic method: remove beetles by trapping/physical removal to reduce their population size; apply a chemical/pesticide to kill the beetles; or introduce a predator/parasite/pathogen (biological control) that harms the beetles.

# Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

**(a) Describe** one environmental problem associated with the release of methane into the atmosphere.

# Question 3

2023 Set 2 ▪ Q3

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Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

**(b) Describe** one factor that could affect the decomposition of the solid waste in a landfill.

# Question 3

2023 Set 2 ▪ Q3

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Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

**(c) Propose** a solution to decrease the amount of methane released from landfills into the atmosphere.

# Question 3

2023 Set 2 ▪ Q3

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There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

**(d) Justify** the solution proposed in part (c) by describing an additional advantage, other than decreasing the amount of methane released from landfills.

# Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

**(e)** The average cow releases 150 liters of methane per day. **Calculate** the amount of methane that was released by all beef cattle raised in the United States in 2021. **Show** your work.

# Question 3

2023 Set 2 ▪ Q3

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Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

**(f)** A typical beef cow needs 11.8 kilograms of food per day, and each hectare of cattle pasture produces 26.2 kilograms of grasses. **Calculate** the number of hectares of

# Question 3

pasture that would be needed to support all beef cattle raised in the United States for one day. **Show** your work.

# Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

**(g)** The average American consumes 2,250 kilocalories of food per day. Beef cattle can produce 2.7 million kilocalories per hectare of land. Corn can produce 30.4 million kilocalories per hectare of land. **Calculate** how many more American people could be

# Question 3

fed if 150 hectares of land was used to grow corn instead of raising beef cattle. **Show** your work.

# Solution 3

**(a)**

**Mark scheme**

- One environmental problem, e.g.: methane traps heat effectively, enhancing the greenhouse effect and leading to climate change/global warming — which can in turn cause melting ice and rising sea levels.

# Solution 3

**(b)**

**Mark scheme**

- One factor, e.g.: the amount/percentage of organic material in the solid waste; the amount/percentage of non-degradable material in the waste; landfill conditions such as oxygen concentration, population of microbes/decomposers, temperature, or moisture; or environmental conditions of the area such as temperature, rainfall, climate, or weather.

# Solution 3

**(c)**

**Mark scheme**

- A solution such as: incinerating waste; composting waste; recycling/reusing non-synthetic organic waste (paper, textiles); installing/using methane collection systems; or burning off/combusting the methane coming from the landfill.

# Solution 3

## (d) Mark scheme

- An additional advantage matching the solution proposed in (c). Incinerating waste: extends the landfill's lifetime, reduces the amount of waste going to the landfill, can be used to generate electricity/heat or income, or reduces land area needed for landfills. Composting waste: extends the landfill's lifetime, produces effective inexpensive fertilizer, or reduces land area needed for landfills. Recycling/reusing organic waste: reduces land needed for landfills, reduces energy/resources needed for new products, or reduces trees cut for new paper. Installing methane collection / burning off methane: can be used to generate electricity, can be used to heat buildings, can generate income, can be used as fuel, or reduces the need for other energy sources.

# Solution 3

## (e)

**Mark scheme**

- Setup (1 pt): 150 L methane/day/cow $\times$ 31,200,000 cows (cattle) $\times$ 365 days/year. Calculation (1 pt): 150 $\times$ 31,200,000 $\times$ 365 $=$ 1,708,200,000,000 L ($\approx$1.7 $\times$ 10^12 L) of methane released by all beef cattle raised in the United States in one year.

# Solution 3

## (f)

**Mark scheme**

- Setup (1 pt): (11.8 kg food/day/cow ÷ 26.2 kg grass produced/ha) × 31,200,000 cows (cattle). Calculation (1 pt): (11.8/26.2) × 31,200,000 ≈ 14,051,908 hectares (≈1.4 × 10^7 ha, or 14.1 million hectares) of pasture needed to support all beef cattle raised in the United States for one day.

# Solution 3

## (g)

**Mark scheme**

- Setup (1 pt): [(30,400,000 kcal/ha − 2,700,000 kcal/ha) ÷ 2,250 kcal/person] × 150 ha — the extra kcal/ha produced by growing corn instead of raising beef cattle, converted to people fed, for 150 hectares. Calculation (1 pt): (27,700,000/2,250) × 150 = 1,846,667 additional people (≈1.8 × 10^6) could be fed if 150 hectares were used to grow corn instead of raising beef cattle.

# Question 1

2022 Set 1 ▪ Q1

Common snapping turtles, *Chelydra serpentina*, are primarily aquatic, but they lay their eggs on land. Researchers are interested in understanding the impact of pollution on turtle nesting sites. The researchers examined nesting sites at two agricultural areas along the floodplain of a river upstream and downstream from a chemical factory that is a known source of aqueous mercury pollution. Turtle eggs, soil, and vegetation samples taken from areas around turtle nests downstream from the chemical factory showed high levels of mercury in a previous study. Mercury was not detected in samples taken upstream from the chemical factory.

[Diagram: "DISTRIBUTION OF TURTLE NESTS ALONG RIVER." A map shows a river winding from top to bottom with an arrow labeled "Direction of Flow" pointing downstream. A "Chemical Factory" sits beside the river partway down, with a "Discharge Pipe" emptying into the river at that point. Along the riverbank are

# Question 1

forested strips labeled "Forest Area" (trees drawn as small pine-tree and round-tree icons). "Area A" is a region upstream of the chemical factory's discharge point (bounded by dashed lines), shown with many nest markers clustered together: a mix of filled circles (•) labeled "Successful turtle nest" and X marks (×) labeled "Unsuccessful turtle nest" in the legend — Area A shows a dense cluster of both successful (•) and unsuccessful (×) nests close together in the forest area. "Area B" is a region downstream of the chemical factory's discharge point (bounded by dashed lines), shown with a sparser, more scattered mix of successful (•) and unsuccessful (×) nest markers, with unsuccessful (×) nests appearing more numerous/closer to the river relative to successful (•) nests, which sit farther back. Legend box: "• Successful turtle nest" and "× Unsuccessful turtle nest."]

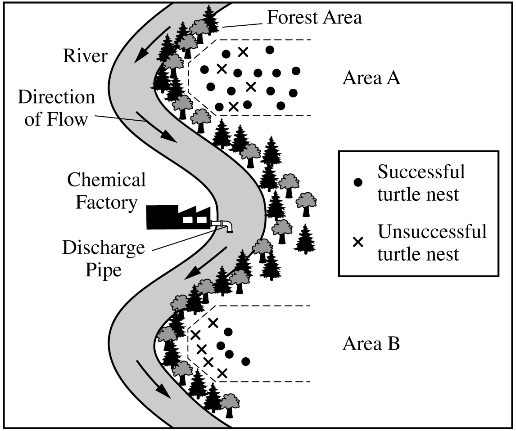
**(a)(i) Identify** the area with the greatest nest success rate, based on the information in the diagram.

# Question 1

**(a)(ii) Identify** the dependent variable in the study.
**(a)(iii)** Based on the information provided, **identify** a likely scientific question for the study.
**(a)(iv) Describe** why researchers measured mercury levels in locations upstream from the factory.
**(a)(v)** There are plans to remove trees and other vegetation along the river bank. **Explain** how this modification could affect the location and number of successful turtle nests in Area B.

# Question 1

DISTRIBUTION OF TURTLE NESTS ALONG RIVER



# Question 1

2022 Set 1 ▪ Q1

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# Question 1

factory's discharge point (bounded by dashed lines), shown with many nest markers clustered together: a mix of filled circles (•) labeled "Successful turtle nest" and X marks (×) labeled "Unsuccessful turtle nest" in the legend — Area A shows a dense cluster of both successful (•) and unsuccessful (×) nests close together in the forest area. "Area B" is a region downstream of the chemical factory's discharge point (bounded by dashed lines), shown with a sparser, more scattered mix of successful (•) and unsuccessful (×) nest markers, with unsuccessful (×) nests appearing more numerous/closer to the river relative to successful (•) nests, which sit farther back. Legend box: "• Successful turtle nest" and "× Unsuccessful turtle nest."]

**(b)(i)** Mercury can affect organisms and ecosystems in many ways. **Describe** how a persistent pollutant, such as mercury, can negatively affect an organism.

**(b)(ii)** **Describe** how a persistent pollutant, such as mercury, can negatively affect an ecosystem.

# Question 1

**(b)(iii)** Researchers measured methylmercury in a location downstream from the factory. **Explain** how methylmercury could be present in the stream.
**(b)(iv)** Researchers claimed that the soil nearest to the river has higher levels of mercury than the field has, and those elevated levels have affected the nesting success for turtles. **Explain** how the pattern shown in the diagram supports or refutes this claim.

# Question 1

2022 Set 1 ▪ Q1

Common snapping turtles, *Chelydra serpentina*, are primarily aquatic, but they lay their eggs on land. Researchers are interested in understanding the impact of pollution on turtle nesting sites. The researchers examined nesting sites at two agricultural areas along the floodplain of a river upstream and downstream from a chemical factory that is a known source of aqueous mercury pollution. Turtle eggs, soil, and vegetation samples taken from areas around turtle nests downstream from the chemical factory showed high levels of mercury in a previous study. Mercury was not detected in samples taken upstream from the chemical factory.

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# Question 1

factory's discharge point (bounded by dashed lines), shown with many nest markers clustered together: a mix of filled circles (•) labeled "Successful turtle nest" and X marks (×) labeled "Unsuccessful turtle nest" in the legend — Area A shows a dense cluster of both successful (•) and unsuccessful (×) nests close together in the forest area. "Area B" is a region downstream of the chemical factory's discharge point (bounded by dashed lines), shown with a sparser, more scattered mix of successful (•) and unsuccessful (×) nest markers, with unsuccessful (×) nests appearing more numerous/closer to the river relative to successful (•) nests, which sit farther back. Legend box: "• Successful turtle nest" and "× Unsuccessful turtle nest."]

**(c)** The turtle study was conducted in an agricultural area. **Describe** how a specific agricultural practice changes the soil in an area.

# Solution 1

## (a)(i)

**Mark scheme**

- Area A (the site/area upstream from the factory) has the greatest nest success rate.

## (a)(ii)

**Mark scheme**

- The dependent variable is turtle nesting success.

# Solution 1

## (a)(iii)

**Mark scheme**

- A likely scientific question: Does mercury content in the turtle's habitat affect common snapping turtle nest success? (Alternatively: Does mercury content in the turtle's habitat affect the location/site of common snapping turtle nests?)

# Solution 1

**(a)(iv)**

**Mark scheme**

- The upstream locations acted as a control group in the study, used to compare against the high-mercury turtle nests found downstream.

# Solution 1

## (a)(v) Mark scheme

- Removing riverbank vegetation could affect nesting as follows (any one): with more open area closer to the river, turtles don't have to travel as far to nest, so they are exposed to higher mercury levels near the river, decreasing the number of successful nests; with less vegetation to take up/remove mercury (heavy metals/endocrine disruptors/pesticides), concentrations in the soil increase, decreasing successful nests; soil erosion along the stream increases, making nest-building harder and decreasing successful nests; or with less vegetation/shade, soil temperature increases and moisture decreases, decreasing successful nests.

# Solution 1

## (b)(i)

**Mark scheme**

- A persistent pollutant like mercury can harm an organism because it bioaccumulates in tissues (it does not break down easily and accumulates over time); mercury is a neurotoxin that disrupts the nervous system/neuron functioning; or it disrupts normal functioning of the brain/kidneys/liver/immune system/reproductive system and can lead to death.

# Solution 1

## (b)(ii)

**Mark scheme**

- A persistent pollutant can harm an ecosystem because it biomagnifies up the food chain, giving top predators very high concentrations (which can cause a trophic cascade if predators die off); or because decreased reproductive success in exposed organisms alters food webs/trophic structure and reduces biodiversity/ecosystem stability.

# Solution 1

## (b)(iii)

**Mark scheme**

- Mercury is likely released into the stream by the factory as a waste product; bacteria/microorganisms in the water and sediments then convert the inorganic mercury into methylmercury.

# Solution 1

## (b)(iv)

**Mark scheme**

- The diagram supports the claim: nests close to the river in Area B, where mercury levels are high, are not successful, while nests farther from the river are successful — supporting the claim that elevated soil mercury reduces nesting success. (Alternatively: Area B, closer to the river, has fewer total/successful nests than Area A, further supporting the claim.)

# Solution 1

## (c) Mark scheme

- Any one specific agricultural practice and its soil effect: tilling/plowing loosens/softens soil and/or removes organic matter, leading to erosion; monocropping removes nutrients and/or moisture; synthetic fertilizer use disrupts soil chemistry; irrigation can cause waterlogging, erosion, and/or salinization; slash-and-burn removes vegetation and upper organic soil layers (though it can add nutrients); heavy machinery use compacts soil; polyculture/cover cropping with nitrogen-fixing plants adds soil nutrients; or manure/organic fertilizer use increases soil moisture content.

# Question 1

2022 Set 2 ▪ Q1

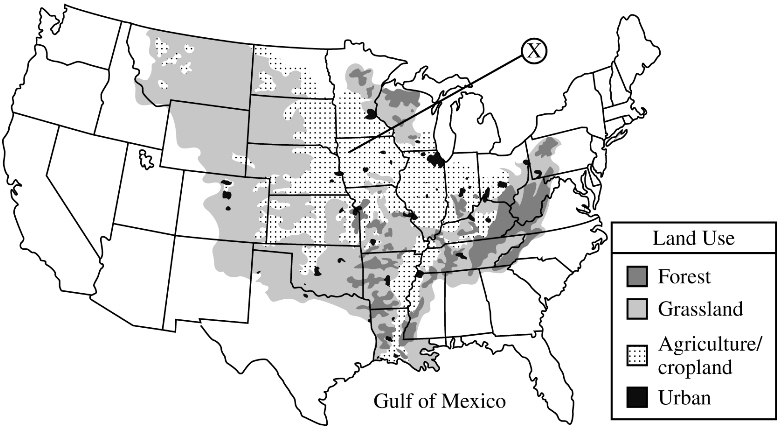
The dead zone in the Gulf of Mexico occurs every summer when winter snow melts and spring rain flows into the Mississippi River. Recent studies have shown that both the total area covered by algae and the depth of the algal mass in the dead zone are increasing.
[Map titled “LAND USE WITHIN THE MISSISSIPPI RIVER WATERSHED”: a map of the continental United States showing the Mississippi River watershed shaded by land use type, with the Gulf of Mexico labeled at the bottom. A point labeled “X” is marked in the upper-central part of the watershed (near the Great Lakes region), connected by a line from the map. Legend “Land Use”: Forest (dark gray shading), Grassland (light gray shading), Agriculture/cropland (dotted/stippled shading), Urban (solid black shading, scattered small patches throughout the watershed, especially clustered in the east and around the Great Lakes).]

# Question 1

**(a)(i)** Various land use practices can have different effects on the waters that surround a dead zone.
**Identify** the land use that covers the least amount of area in the Mississippi River watershed, based on the diagram.
**(a)(ii) Describe** one way that the land use practice at location X in the diagram could contribute to the dead zone in the Gulf of Mexico.
**(a)(iii) Describe** one way that urban areas in the Mississippi River watershed could contribute to the dead zone in the Gulf of Mexico.

# Question 1

LAND USE WITHIN THE MISSISSIPPI RIVER WATERSHED



# Question 1

2022 Set 2 ▪ Q1

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# Question 1

**(b)(i)** The dead zone in the Gulf of Mexico has both economic and environmental effects for coastal communities.
**Describe** how a dead zone affects marine organisms living in the Gulf of Mexico.
**(b)(ii) Describe** one economic effect on communities along the Gulf of Mexico that can result from the presence of the dead zone.
**(b)(iii) Describe** one factor that causes the area of the dead zone in the Gulf of Mexico to increase in the summer months.

# Question 1

2022 Set 2 ▪ Q1

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# Question 1

**(c)(i)** Researchers want to examine the effect of riparian vegetation buffers on water quality in streams in agricultural areas. Researchers will measure the water nutrient concentrations over the course of one year. The study sites are located 100 meters downstream from areas either with or without riparian vegetation buffers.
**Identify** a testable hypothesis for the study.
**(c)(ii) Describe** a control that the researchers could use in the study.
**(c)(iii) Identify** one water quality test, other than measuring nitrates or phosphates, that the researchers could use to evaluate how riparian vegetation buffers affect water quality.
**(c)(iv)** During the investigation, researchers discovered that some of the land next to one of the streams with a riparian vegetation buffer is going to be converted from cornfields into a large-scale concentrated animal feeding operation. **Explain** one way that this change in land use could alter the results of the study.

# Solution 1

## (a)(i)

**Mark scheme**

- Urban — urban land use covers the least area of the Mississippi River watershed shown in the diagram.

# Solution 1

## (a)(ii)

**Mark scheme**

- Any one way land use at location X could contribute to the dead zone: fertilizer applied to croplands washes into streams/rivers and feeds algae growth once it reaches the Gulf; concentrated animal feeding operations (CAFOs) generate large amounts of organic waste that moves into streams and rivers, feeding algae growth in the Gulf; treated or untreated (overflow) sewage released from wastewater treatment plants feeds algae growth in the Gulf.

# Solution 1

## (a)(iii)

**Mark scheme**

- Any one way urban areas could contribute to the dead zone: wastewater treatment facilities in urban areas may release nutrients in treated wastewater and/or overflows that flow into the Gulf; impervious surfaces in urban areas increase runoff of lawn fertilizers or high-phosphate detergents that move onto pavement and flow into the Gulf.

# Solution 1

**(b)(i)**

**Mark scheme**

- Any one effect: many organisms are forced to migrate or die because of low dissolved oxygen levels in the water (hypoxia); many organisms are forced to migrate or die because algal blooms block sunlight from reaching submerged aquatic vegetation.

# Solution 1

**(b)(ii)**

**Mark scheme**

- Any one economic effect: decreased fish catch / decreased income for the fishing industry; decreased tourism / lower tourism revenues; increased fuel costs for fishing vessels that must travel farther to find fish, decreasing income/profits; increased costs for consumers due to a limited supply of fish.

# Solution 1

## (b)(iii)

**Mark scheme**

- Any one factor: increased runoff of nitrates/phosphates/potassium from fertilizer used during the growing season increases algal growth in summer; increased precipitation/snowmelt/water volume carries more fertilizer runoff from urban or agricultural areas, increasing algal growth; higher water temperatures in summer decrease dissolved oxygen concentration (warm water holds less DO than cold water); increased runoff of fertilizer or high-phosphate detergents used in urban areas increases algal growth in summer.

# Solution 1

## (c)(i)

### Mark scheme

- Any testable hypothesis of the form: if riparian vegetation buffers are present in agricultural areas, then the level of nitrates/phosphates/nutrients downstream will be lower (or higher, or the same) than in areas without riparian buffers.

## (c)(ii)

### Mark scheme

- The control is stream sites located 100 meters downstream from areas WITHOUT riparian vegetation buffer zones.

# Solution 1

**(c)(iii)**

**Mark scheme**

- Any one water quality test other than nitrates or phosphates: turbidity; total suspended solids (TSS); dissolved oxygen; water temperature; fecal coliform; conductivity; pH; biological oxygen demand (BOD).

# Solution 1

## (c)(iv) Mark scheme

- Any one explanation: water quality would decline from increased nutrients/coliform bacteria in runoff because animal waste near the new CAFO is high in nutrients/coliform bacteria; water quality would decline from increased turbidity/total suspended solids because particles from animal waste enter the stream / streambed disruption increases; water quality would decline from increased water temperature because the increased turbidity/suspended solids absorb more sunlight/heat; water quality would decline from increased conductivity because of increased water temperature/dissolved salts near the CAFO; water quality would decline from antibiotics/veterinary drugs present in runoff from livestock operations (not used on the original cornfield crop). This

# Solution 1

confounds the study because conditions change at the riparian-buffer site independent of the buffer treatment itself.

# Question 2

2022 Set 2 ▪ Q2

Biologists collected data on the abundance of lizards on several Pacific islands with and without mongoose populations. The surveys were conducted at different locations on the islands by counting the number of lizards observed per hour and included habitats with both undisturbed areas and anthropogenically disturbed areas. [Scatter/line graph titled "LIZARD NUMBERS ON PACIFIC ISLANDS". Y-axis: "Lizards Counted per Hour", logarithmic scale from $10^0$ to $10^3$. X-axis: "Habitat Types", with categories in order from "Undisturbed" to "Highly disturbed": Primary Forest, Secondary Forest, Clearings, Gardens, Sugarcane Fields, Hotels, Parks, and Walking Trails. Two data series with individual data points and a smoothed trend curve for each: "Mongoose-free islands" (filled circles, solid curve) and "Mongoose-present islands" (open squares, dashed curve). Both curves rise from Primary Forest, peak around Clearings, Gardens (mongoose-free peak $\approx$ 50

# Question 2

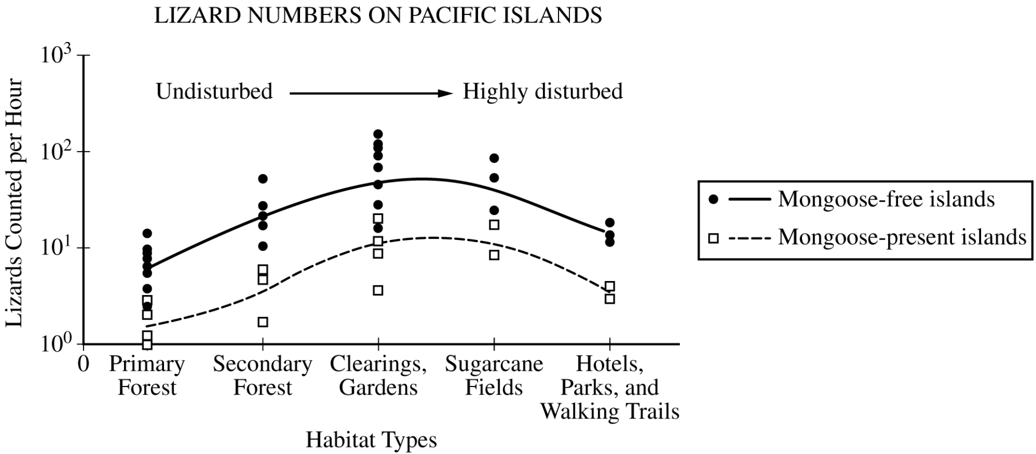
lizards/hour; mongoose-present peak $\approx$ 10 lizards/hour), then decline toward Hotels, Parks, and Walking Trails (mongoose-free $\approx$ 15 lizards/hour; mongoose-present $\approx$ 3 lizards/hour). At every habitat type, the mongoose-free (solid) curve lies above the mongoose-present (dashed) curve.]

**(a)(i)** The graph shows data collected by biologists on lizard numbers on several Pacific islands.

Based on the data in the graph, **identify** the habitat type with the greatest number of lizards.

**(a)(ii)** Based on the data in the graph, **describe** the relationship between the lizard numbers observed on islands with and without mongoose populations.

# Question 2



LIZARD NUMBERS ON PACIFIC ISLANDS
$10^3$
$10^2$
$10^1$
$10^0$
0
Lizards Counted per Hour
Undisturbed
Highly disturbed
Primary Forest
Secondary Forest
Clearings, Gardens
Sugarcane Fields
Hotels, Parks, and Walking Trails
Habitat Types
Mongoose-free islands
Mongoose-present islands

# Question 2

2022 Set 2 ▪ Q2

Biologists collected data on the abundance of lizards on several Pacific islands with and without mongoose populations. The surveys were conducted at different locations on the islands by counting the number of lizards observed per hour and included habitats with both undisturbed areas and anthropogenically disturbed areas.

[Scatter/line graph titled "LIZARD NUMBERS ON PACIFIC ISLANDS". Y-axis: "Lizards Counted per Hour", logarithmic scale from $10^0$ to $10^3$. X-axis: "Habitat Types", with categories in order from "Undisturbed" to "Highly disturbed": Primary Forest, Secondary Forest, Clearings, Gardens, Sugarcane Fields, Hotels, Parks, and Walking Trails. Two data series with individual data points and a smoothed trend curve for each: "Mongoose-free islands" (filled circles, solid curve) and "Mongoose-present islands" (open squares, dashed curve). Both curves rise from Primary Forest, peak around Clearings, Gardens (mongoose-free peak $\approx$ 50 lizards/hour; mongoose-present peak $\approx$ 10 lizards/hour), then decline toward

# Question 2

Hotels, Parks, and Walking Trails (mongoose-free $\approx$ 15 lizards/hour; mongoose-present $\approx$ 3 lizards/hour). At every habitat type, the mongoose-free (solid) curve lies above the mongoose-present (dashed) curve.]

**(b)** Globally, islands vary in size, location, and habitat.

Based on the theory of island biogeography, **describe** the characteristics of an island with the greatest species diversity.

# Question 2

2022 Set 2 ▪ Q2

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**(c)(i)** Island ecosystems are often threatened by invasive species, such as the mongoose populations studied in the survey.
**Describe** one environmental problem caused by invasive animal species.
**(c)(ii)** Invasive species are often pests. **Make a claim** that proposes one way to control pest species.
**(c)(iii)** **Justify** the solution proposed in (c)(ii) by providing an additional benefit of the solution.

# Question 2

2022 Set 2 ▪ Q2

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# Question 2

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**(d)(i)** Islands provide humans with many ecosystem services. However, humans may alter ecosystems when they obtain these services. Large-scale commercial sugarcane farming on the Pacific islands has led to significant ecological damage.

**Identify** a provisioning ecosystem service provided by primary forests.

**(d)(ii)** Based on the data in the graph, **explain** how replacing primary forests with sugarcane fields may have affected the number of lizards counted on the mongoose-free Pacific islands.

**(d)(iii)** The long-term use of monocultures in commercial sugarcane farming is one cause of the ecological damage. **Describe** one problem associated with monocultures.

# Question 2

2022 Set 2 ▪ Q2

Biologists collected data on the abundance of lizards on several Pacific islands with and without mongoose populations. The surveys were conducted at different locations on the islands by counting the number of lizards observed per hour and included habitats with both undisturbed areas and anthropogenically disturbed areas.

[Scatter/line graph titled "LIZARD NUMBERS ON PACIFIC ISLANDS". Y-axis: "Lizards Counted per Hour", logarithmic scale from $10^0$ to $10^3$. X-axis: "Habitat Types", with categories in order from "Undisturbed" to "Highly disturbed": Primary Forest, Secondary Forest, Clearings, Gardens, Sugarcane Fields, Hotels, Parks, and Walking Trails. Two data series with individual data points and a smoothed trend curve for each: "Mongoose-free islands" (filled circles, solid curve) and "Mongoose-present islands" (open squares, dashed curve). Both curves rise from Primary Forest, peak around Clearings, Gardens (mongoose-free peak $\approx$ 50 lizards/hour; mongoose-present peak $\approx$ 10 lizards/hour), then decline toward

# Question 2

Hotels, Parks, and Walking Trails (mongoose-free $\approx$ 15 lizards/hour; mongoose-present $\approx$ 3 lizards/hour). At every habitat type, the mongoose-free (solid) curve lies above the mongoose-present (dashed) curve.]

**(e)** One solution to the ecological damage of monocultures is to use a form of crop rotation using legumes.

**Describe** an advantage of crop rotation using legumes on soil fertility.

# Solution 2

## (a)(i)

**Mark scheme**

- Clearings/Gardens — this habitat type has the greatest number of lizards in the graph.

## (a)(ii)

**Mark scheme**

- Any one description: lizard populations are smaller on islands where mongooses are present than on mongoose-free islands; lizard populations are larger on mongoose-free islands than on islands with mongooses; the relationship between lizard numbers and mongoose population is an inverse (negative) relationship.

# Solution 2

**(b)**

**Mark scheme**

- A large island located near the mainland will have the greatest species diversity — per island biogeography theory, larger area supports a larger population/lower extinction rate, and proximity to the mainland increases the immigration (colonization) rate.

# Solution 2

## (c)(i)

**Mark scheme**

- Any one environmental problem: invasive species outcompete native species for resources, causing food web disruptions/trophic cascades/habitat loss; invasive species outcompete or prey on native organisms, decreasing biodiversity/reducing native population sizes.

# Solution 2

**(c)(ii)**

**Mark scheme**

- Any one claim proposing pest control: introduce biological controls (natural predators of the species) to reduce pest numbers; use chemical controls such as pesticides to kill off pests; use manual/mechanical methods to remove plant species; trap/hunt animal species and remove/kill them from the area.

# Solution 2

## (c)(iii)

### Mark scheme

- Justification must match the solution proposed in (c)(ii): biological control, manual/mechanical removal, or trapping/hunting is justified as least likely to harm other species because the pest species can be specifically targeted, and harmful synthetic chemicals are not introduced into the environment (manual/trapping methods can also cite financial gain from selling killed pest organisms); chemical control (pesticides) is justified as a quick/efficient method to reduce/eliminate the pest species.

# Solution 2

**(d)(i)**

**Mark scheme**

- Any one provisioning ecosystem service from primary forests: timber/lumber/wood; medicine; food.

# Solution 2

## (d)(ii)

**Mark scheme**

- Any one explanation: the cleared land is preferred habitat for the lizards, leading to increased lizard numbers in the sugarcane fields compared to forests; the cleared land has fewer predators, leading to increased lizard numbers in the sugarcane fields compared to forests; the cleared land has more food for the lizards, leading to increased lizard numbers in the sugarcane fields compared to forests.

# Solution 2

## (d)(iii)

**Mark scheme**

- Any one problem associated with monocultures: decreased genetic diversity of the monoculture species; decreased species diversity; increased susceptibility of the monoculture to disease/pests; depletion of nutrients from the soil; increased use of irrigation water/fertilizer/pesticide.

# Solution 2

**(e)**

**Mark scheme**

- Any one advantage of crop rotation using legumes: improved nitrogen fixation in the soil; less nitrogen-based fertilizer required.

# Question 1

2021 Set 2 ▪ Q1

Soil erosion is one of the most serious soil-degrading processes. Each year tons of soil erode from cropland, pastures, forests, and other places. The amount of erosion varies dramatically among various land-use types. The figure above shows the effects of different agricultural practices and slopes on annual erosion rates.
[Line graph titled "EFFECT OF PERCENT SLOPE ON ANNUAL EROSION FOR FOUR AGRICULTURAL PRACTICES"; x-axis "Slope (%)" from 0 to 30 (gridlines at 0, 5, 10, 15, 20, 25, 30); y-axis "Annual Erosion (tons/acre)" from 0 to 30 (gridlines at 0, 5, 10, 15, 20, 25, 30). A dashed horizontal line at about y = 4 is labeled "T = tolerable loss". Four curves, all starting near (0,0): "Tillage" (solid thick line) rises steeply, reaching about 12 tons/acre at 5% slope and about 30 tons/acre at roughly 7-8% slope (curve goes off the top of the chart just past slope 7%); "No-till" (dotted line) rises more gradually, crossing the tolerable-loss line around 10% slope and

# Question 1

reaching about 29 tons/acre at 30% slope; "No-till + cover crop" (dashed line) rises even more gradually, crossing the tolerable-loss line around 15% slope and reaching about 20 tons/acre at 30% slope; "Crop rotation" (thin solid line) rises the most gradually, staying below the tolerable-loss line until about 20% slope and reaching only about 8 tons/acre at 30% slope.]

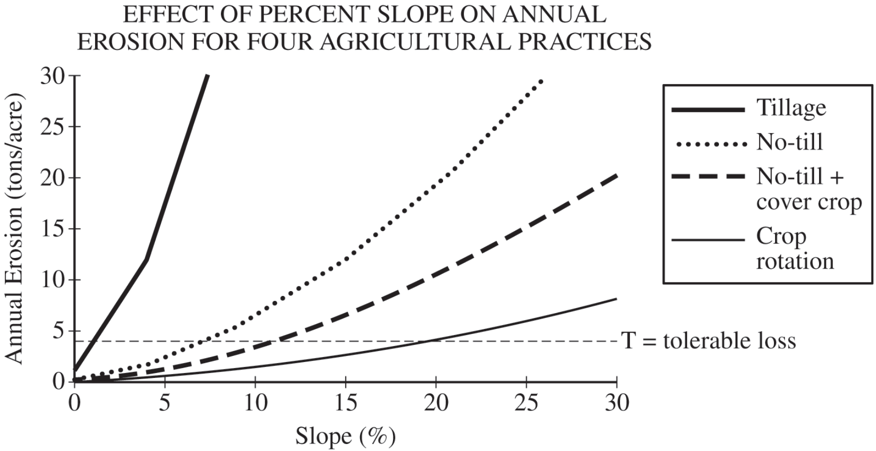
**(a)(i)** Identify the scientific question that resulted in the data presented in the graph.

**(a)(ii)** Identify the agricultural practice that could be used on a 15% slope without leading to a higher than tolerable loss of soil.

**(a)(iii)** Describe the effect of adding a cover crop compared to using the no-till method.

**(a)(iv)** Identify one natural mechanism of soil erosion.

# Question 1


EFFECT OF PERCENT SLOPE ON ANNUAL
EROSION FOR FOUR AGRICULTURAL PRACTICES
Annual Erosion (tons/acre)
0
5
10
15
20
25
30
Slope (%)
0
5
10
15
20
25
30
T = tolerable loss
Tillage
No-till
No-till + cover crop
Crop rotation