Past-paper walk-through

Soil Formation and Erosion ▪ 4.2

eXercise

Questions in this set

- 2024 Set 1 Q2
- 2024 Set 2 Q1
- 2022 Set 1 Q1
- 2021 Set 2 Q1
- 2016 Q4
- 2014 Q3

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

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

[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

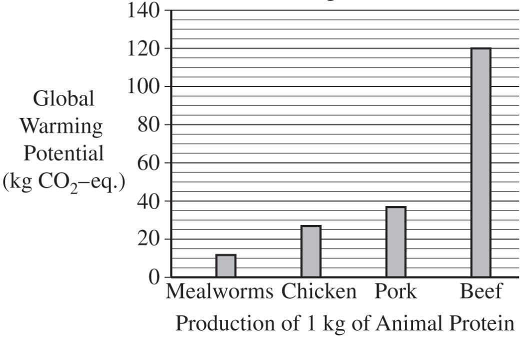
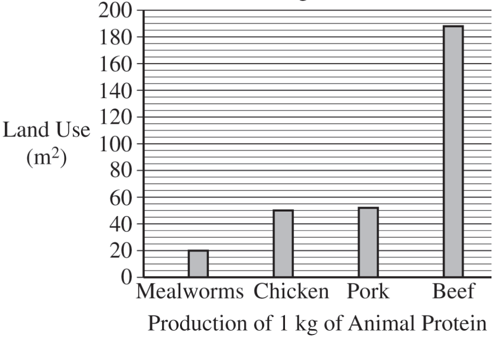


Figure 2



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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.

Question 2

2024 Set 1 ▪ Q2

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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.

Question 2

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.

Question 2

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.

Question 2

2024 Set 1 ▪ Q2

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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

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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

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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

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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 CO_2 (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:

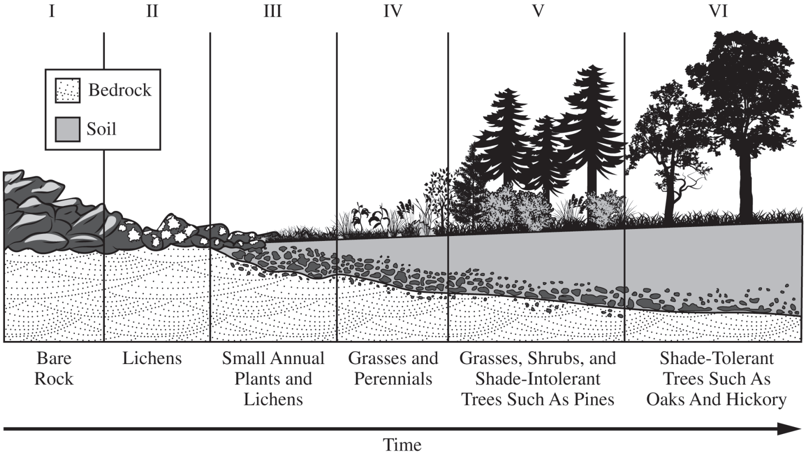
- Stage I: Bare Rock

Question 1

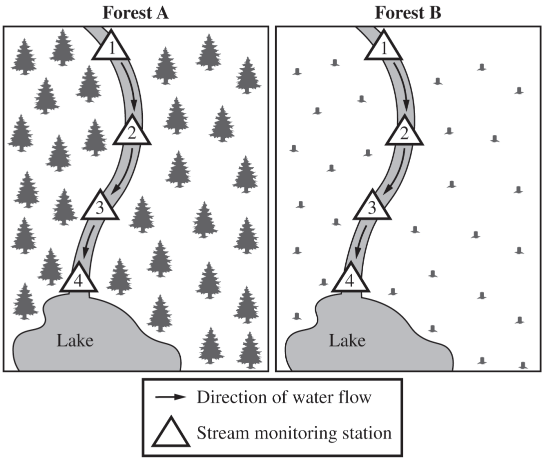
- Stage II: Lichens
- Stage III: Small Annual Plants and Lichens
- Stage IV: Grasses and Perennials
- Stage V: Grasses, Shrubs, and Shade-Intolerant Trees Such As Pines
- Stage VI: Shade-Tolerant Trees Such As Oaks And Hickory]

(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

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

Question 1

2024 Set 2 ▪ Q1

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

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2024 Set 2 ▪ Q1

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

Question 1

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(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

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(f) Identify the independent variable in the experiment.

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

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2024 Set 2 ▪ Q1

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

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2024 Set 2 ▪ Q1

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(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

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(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 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

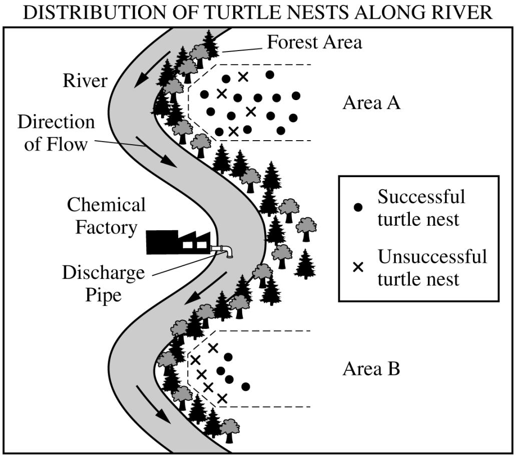
forested strips labeled "Forest Area" (trees drawn as small pine-tree and round-tree icons). "Area A" is a region upstream of the chemical factory's discharge point (bounded by dashed lines), shown with many nest markers clustered together: a mix of filled circles ( ) labeled "Successful turtle nest" 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
Forest Area
River
Area A
Direction of Flow
Successful turtle nest
Unsuccessful turtle nest
Chemical Factory
Discharge Pipe
Area B

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."]

(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.

[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 forested strips labeled "Forest Area" (trees drawn as small pine-tree and round-tree icons). "Area A" is a region upstream of the chemical

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

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.]

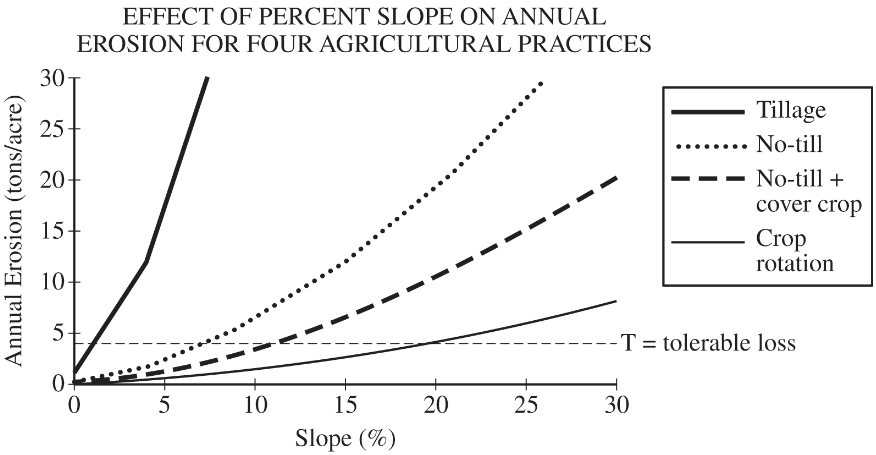
(a)(i) Identify the scientific question that resulted in the data presented in the graph.

(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)
30
25
20
15
10
5
0
0
5
10
15
20
25
30
Slope (%)
T = tolerable loss
Tillage
No-till
No-till + cover crop
Crop rotation