AP® Environmental Science
2011 Scoring Guidelines

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AP® ENVIRONMENTAL SCIENCE
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Question 1

(a) As mentioned in the article, there are several possible explanations for the increase in mountain pine beetles.

(i) Provide one reason why fire-suppression policies lead to increased beetle activity.
(*1 point; only the first answer is scored.*)

- Suppression leads to increased numbers of trees/more food/denser forests.
- Suppression allows weaker, more vulnerable trees that would have been weeded out by fire to survive.
- Suppression leads to less diversity of tree species, so beetles spread more quickly between trees.
- Suppression leads to equal/even-age stands of mature trees, which the beetles prefer.

(ii) Reduced winter mortality of beetle larvae is likely a consequence of global climate change. Describe TWO ways that the activities of the beetles might enhance climate change.
(*2 points; 1 point for each activity. Only the first two answers are scored.*)

- Less carbon dioxide is removed by trees (less photosynthesis/primary production/carbon sinks/carbon sequestration).
- Higher levels of dead tree matter release more carbon dioxide through decomposition.
- Burning of forests as a result of infestation (dead trees) releases carbon dioxide.

Note: Carbon dioxide released by beetle respiration is NOT an acceptable answer.

(b) The widespread death of trees leads to a series of changes in a forest ecosystem. Identify TWO physical changes that occur in the forest ecosystem as the result of the death of mature trees. For each physical change you identify, describe an impact of that change on the forest ecosystem.
(*4 points; 1 point for each identification and 1 point for each description. The description must be LINKED to the identification. Only the first two answers are scored.*)

Physical change	**Impact on ecosystem**
Habitat loss (loss of foliage, branches, physical structures provided by trees)	• Loss of biodiversity. • Loss of shelter (nesting/breeding). • Animal species migrate or die. • Loss of food. • Increased competition for food/shelter.
Increased sunlight reaching the ground	• Growth of younger trees because of reduced competition for light. • Shift in species because of changing light conditions. • Increased habitat for species in downed trees and/or snags. • Loss of species that cannot tolerate higher temperatures. • Increased evaporation from waterways reduces flows. • Faster evaporation of snowcover reduces snowmelt in spring and reduces flows. • Increased sunlight results in decreased snowcover.

Question 1 (continued)

Increased erosion/decreased root systems/increased runoff	• Loss of nutrients for plants. • Loss of root zone for plant stability. • Increased siltation/sedimentation. • Change in stream and river depth leads to changes in plant and animal species. • Changes in water clarity leads to reduced primary productivity. • Mortality of animal and plant species that are buried by sediment.
Less absorption of precipitation by trees	• Increased runoff. • Increased erosion. • Loss of nutrients (leaching or runoff). • Mortality of plant species (waterlogging). • Mortality or migration of animal species. • Decreased local water vapor/drier climate.
Increased flooding	• Loss of nutrients (leaching). • Mortality of plant species (waterlogging). • Mortality or migration of animal species.
Increased soil temperature	• Changes in plant growth. • Changes in soil communities (microbes and invertebrates).
Downed trees or snags	• Increased habitat for species. • Risk of catastrophic fires. • Increased nutrients from tree decomposition.

(c) As the article states, the number of managed honeybee colonies has dropped significantly over the past few decades. Describe TWO specific economic consequences of the collapse of the managed honeybee colonies.
(*2 points; 1 point for each consequence linked to a description. Only the first two answers are scored.*)

Economic consequence	**Description**
• Increased costs/prices	• For food crops. • For beekeepers' services/replacement of hives. • For manual pollination. • For attraction of native pollinators by planting wildflowers/native flowering plants OR providing nesting sites and safe foraging areas. • For better nutrition/medicine for bees.
• Lower revenue/sales • Loss of jobs	• Because of lower crop yields. • Because of lower honey production.

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Question 1 (continued)

(d) Pollination by native insects is considered an ecosystem service. Identify a different ecosystem service and explain how that service benefits human society.
(*2 points; 1 point for the identification and 1 point for its linked benefit. Only the first answer is scored.*)

Ecosystem service	Benefit
Control of pests with natural predators	• Reduces incidence of disease (vector-borne). • Reduces need for pesticides. • Reduced crop losses.
Waste disposal/treatment	• Decomposition reduces amount of waste. • Recycles nutrients (plant growth). • Detoxification, removal of pollutants.
Filtering/purification of water by soils and plants	• Reduces costs of providing safe drinking water. • Less contamination/fewer waterborne diseases.
Storage and regulation of water supplies (water cycle)	• Reduces costs of creating fresh water (reverse osmosis). • Supports growth of agricultural crops. • Allows transport of goods. • Allows manufacturing of goods. • Water is necessary for survival.
Disposal/dilution of fecal waste	• Reduced incidence of disease. • Reduced cost of sewage treatment.
Cycling of nutrients (such as nitrogen/phosphorus)	• Reduces use of inorganic/synthetic fertilizers. • Recycles nutrients (plant growth).
Release of oxygen by plants (oxygen cycle)	• Necessary for human survival.
Prevention of soil erosion (roots)	• Reduces costs of soil amendment/fertilizer.
Flood control and moderation of the effects of severe storms (storm surges) through absorption of water	• Protection of human lives. • Lower cost for loss of human property.
Lumber/timber	• Building, fuel, paper products. • Provides income for loggers, paper industry. • Difficult or expensive to replace/duplicate (synthetics often use petrochemicals).
Cycling of carbon	• Vital to crop growth. • Helps in moderation of global temperature.
Medicines to treat diseases	• Provides income to harvesters. • Improves quality of human life (e.g., cancer and diabetes drugs).
Genes for resistance to pathogens and crop pests	• Reduces costs of pesticides. • Reduces use of fossil fuels.
Fish, game, fruit, nuts	• Source of food for hunters, gatherers, fishers.
Soil formation, maintenance of soil nutrients	• Reduces costs of fertilizer/soil amendment.

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Question 2

(a) Explain how an increase in the amount of dissolved CO_2 in ocean water results in a decrease in the pH of ocean water.
(*1 point for the following*)

- When carbon dioxide dissolves in the ocean, it forms an acid (carbonic acid or H_2CO_3).

(b) Explain why the movement of carbon into the ocean has been increasing since 1850.
(*2 points; 1 point for each of the following*)

- The concentration of carbon or carbon dioxide in the atmosphere has increased.
- The source of the increase in carbon or carbon dioxide concentration in the atmosphere is the burning of fossil fuels.

(c) In order to model the effects of ocean acidification on coral reefs, some simplifying assumptions can be made. Use the assumptions in the table below to perform the calculations that follow.

Assume that the total global area of corals growing in reefs is 2.5×10^{11} m^2.
Assume that corals grow only vertically and that the average vertical growth rate of corals is 3 mm/year.
Assume that the average density of $CaCO_3$ in corals is 2×10^3 kg/m^3.

(i) Calculate the current annual global increase in volume, in m^3, of $CaCO_3$ in coral reefs. Show all steps in your calculation.
(*2 points; 1 point for a correct setup and 1 point for the correct answer*)

Units are not required in the answer; however, students must show the calculation in order to receive credit for the correct solution.

$$2.5 \times 10^{11}\ \text{m}^2 \times \frac{3\ \text{mm}}{\text{year}} \times \frac{1\ \text{m}}{1 \times 10^3\ \text{mm}} = 7.5 \times 10^8\ \text{m}^3/\text{year}$$

Or

$$2.5 \times 10^{11}\ \text{m}^2 \times \frac{3 \times 10^{-3}\ \text{m}}{\text{year}} = 7.5 \times 10^8\ \text{m}^3/\text{year}$$

Notes
- Students who write the answer as a word problem may earn points.
- Solutions to the question that use alternative setups that produce a correct answer also earn points.
- Equivalent correct answers (e.g., 750,000,000 m^3) are acceptable.

Question 2 (continued)

(ii) Calculate the current annual global increase in mass, in kg, of $CaCO_3$ in coral reefs. Show all steps in your calculation.
(*2 points; 1 point for a correct setup and 1 point for the correct answer*)

Units are not required in the answer; however, students must show the calculation in order to receive credit for the correct solution.

$$\frac{7.5 \times 10^8 \text{ m}^3}{\text{year}} \times \frac{2 \times 10^3 \text{ kg}}{1 \text{ m}^3} = 1.5 \times 10^{12} \text{ kg/year}$$

Notes

- Students who write the answer as a word problem may earn points.
- Solutions to the question that use alternative setups that produce a correct answer also earn points.
- Equivalent correct answers (e.g., 1,500,000,000,000 kg or 15×10^{11} kg) are acceptable.
- Incorrect answers transferred from (c)(i) can still earn full credit if used correctly.

(iii) Because of ocean acidification, it is expected that in 2050 the mass of $CaCO_3$ deposited annually in coral reefs will be 20 percent less than is deposited currently. Calculate how much less $CaCO_3$, in kg, is expected to be deposited in 2050 than would be deposited if ocean water pH were to remain at its current value.
(*2 points; 1 point for a correct setup and 1 point for the correct answer*)

Units are not required in the answer; however, students must show the calculation in order to receive credit for the correct solution.

$$0.2 \times 1.5 \times 10^{12} \text{ kg} = 3 \times 10^{11} \text{ kg}$$

Notes

- Students who write the answer as a word problem may earn points.
- Solutions to the question that use alternative setups that produce a correct answer also earn points.
- Equivalent correct answers (e.g., 300,000,000,000 kg or 0.3×10^{12} kg) are acceptable.
- Incorrect answers transferred from (c)(ii) can still earn full credit if used correctly.

Question 2 (continued)

(d) Identify and describe one likely negative environmental impact of the loss of coral reefs.
(*2 points; 1 point for correctly identifying a negative impact and 1 point for a correct description of that impact. Only the first answer is scored.*)

The impact must be environmental — economic and societal impacts are not acceptable. The impact and the description must be correctly linked; however, students can earn a point for a description without earning a point for an impact.

Impact	Description
Loss of habitat	• Elimination of a food source for marine life • Loss of breeding grounds for fish and bird species • Loss of shelter/hiding places
Loss of biodiversity or species diversity/richness/evenness	• Extinction or decrease in populations of marine organisms
Decreased protection of coastal areas from waves/storm surges	• Destruction of coastal habitats • Accelerated erosion of shoreline habitat
Loss of carbon sink	• Less carbon storage in coral reefs

(e) Identify one environmental problem (other than one due to ocean acidification or loss of coral reefs) that affects marine ecosystems on a global scale.
(*1 point; only the first answer is scored.*)

Any of the following are correct responses:
- Overfishing
- Destructive fishing practices (e.g., bottom trawling, drift netting)
- Increased ocean temperatures
- Introduction of invasive species
- Nutrient pollution/Eutrophication
- Hypoxia/Dead zones
- Garbage/plastic debris (e.g., Great Pacific Garbage Patch)
- Oil spills/Off-shore oil drilling
- Mercury pollution

Note: Ocean acidification and loss of coral reefs are not acceptable answers.

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Question 3

(a) Iceland's position on the graph is due in part to its access to geothermal energy sources. Describe how electricity is generated from a geothermal source.
(*2 points; 1 point for indicating how steam is produced to turn a turbine and 1 point for stating that the energy from the turbine is used to run a generator that produces electrical current*)

Steam production (thermal energy into mechanical energy). Any of the following are correct responses:

- High-pressure hot water is pumped out of the earth and put into a low-pressure container to produce steam, which will in turn run a turbine (flash steam plant).
- Wells are drilled, and steam is piped directly to turn a turbine (dry steam plant).
- Hot water is pumped out of the earth; a heat exchanger is used to heat another liquid to produce vapor that is then used to turn a turbine (binary cycle).

Electrical production (mechanical energy into electrical energy)

- The energy from the turbine is used to run a generator.

(b) Despite its low GDP per capita and low annual electrical energy consumption per capita, China has become the world's largest emitter of CO_2. Explain this apparent contradiction.
(*1 point*)

Although the per capita electrical energy consumption is low, China is the most populous country on the planet. The sum of individual consumption is large.

(c) In addition to contributing to increased atmospheric CO_2 concentrations, China is facing other air pollution issues related to the generation of electricity. Identify one such issue and describe the impact it has on human health.
(*2 points; 1 point for identifying an issue and 1 point for explaining its impact on human health*)

Students can earn 1 point for naming an air pollution issue without mentioning an impact on human health. In order to earn both points, students must correctly link the impact on human health to the air pollution issue.

Issue (1 point)	**Impact on human health (1 point)**
SO_2 or SO_x emissions from coal-burning power plants	• Respiratory irritant • Aggravate asthma, bronchitis • Can lead to emphysema • Throat irritant
Particulate matter	• Decreases lung function (lung irritant) • Aggravates asthma • Throat irritant
NO_x from coal and petroleum combustion	• Respiratory irritant • Aggravates heart disease
Ozone, PAN from photochemical smog	• Lung irritant • Eye irritant

Question 3 (continued)

Hg from coal-burning power plants — deposition into surface waters	• Neurotoxin • Hearing loss • Impaired ability to learn
SO_x or NO_x aerosols from acid rain	• Lung irritant • Aggravate asthma

Note: Students will not receive credit for identifying the Asian brown cloud, smog, or photochemical smog as an issue. They must identify a specific component and describe a health impact associated with that component in order to earn 2 points.

(d) Two countries shown on the graph have developed domestic energy sources: sugarcane in Brazil and tar sands in western Canada.

(i) Choose EITHER sugarcane or tar sands, then briefly describe the process of fuel production from that energy source.
(*2 points; 1 point for describing the extraction process and 1 point for describing how the fuel is processed*)

Sugarcane	
Extraction (1 point)	**Processing (1 point)**
Sugarcane is harvested and crushed. OR Sucrose is extracted from the sugarcane.	• The sucrose or mash is fermented to produce ethanol AND/OR bagasse (waste product) is collected after the sugarcane is processed.

OR

Tar Sands	
Extraction (1 point)	**Processing (1 point)**
Tar sands are extracted by surface mining.	• Tar sands are treated with hot water to extract the oil (bitumen). • Tar sands are treated with steam to extract the bitumen.

Question 3 (continued)

(ii) Describe TWO disadvantages of using the energy source that you chose in part (d)(i).
(*2 points; 1 point for each disadvantage described for EITHER tar sands or sugarcane*)

Tar Sands
- Nonrenewable resource.
- Habitat destruction as a result of surface mining.
- Low net energy yield.
- Requires large amounts of water to produce.
- Produces large amounts of contaminated water.
- Requires conventional oil to produce oil from tar sands.
- Combustion of a fossil fuel — greenhouse gases are produced.
- Large amounts of mining waste are produced.
- Limited distribution of tar sand deposits.
- Processing requires combusting a fossil fuel.

Sugarcane
- Tropical rainforests are cut down to plant sugarcane, which thus decreases biodiversity.
- Fertilizer is used to increase crop yield:
  - Runoff will lead to eutrophication; or
  - Cost of producing sugarcane increases.
- Soil degradation.
- Requires large amounts of water.
- Competition between its use as a fuel and a food product will increase the cost of food.
- Ethanol is more corrosive to engine parts than traditional gasoline.
- Ethanol provides fewer miles per gallon than gasoline.
- Cannot be grown in all climates.
- Monoculture.
- Increased use of pesticides to increase crop yield.

(iii) Which of the two energy sources is more sustainable? Justify your answer with an explanation.
(*2 points; 1 point for the correct choice and 1 point for a correct explanation*)

Sugarcane is more sustainable, and any of the following is a correct explanation:
- Renewable resource — sugarcane can be replanted.
- Not a fossil fuel — new carbon is being consumed instead of old carbon.
- Little toxic sludge and land destruction in comparison with harvesting tar sands.

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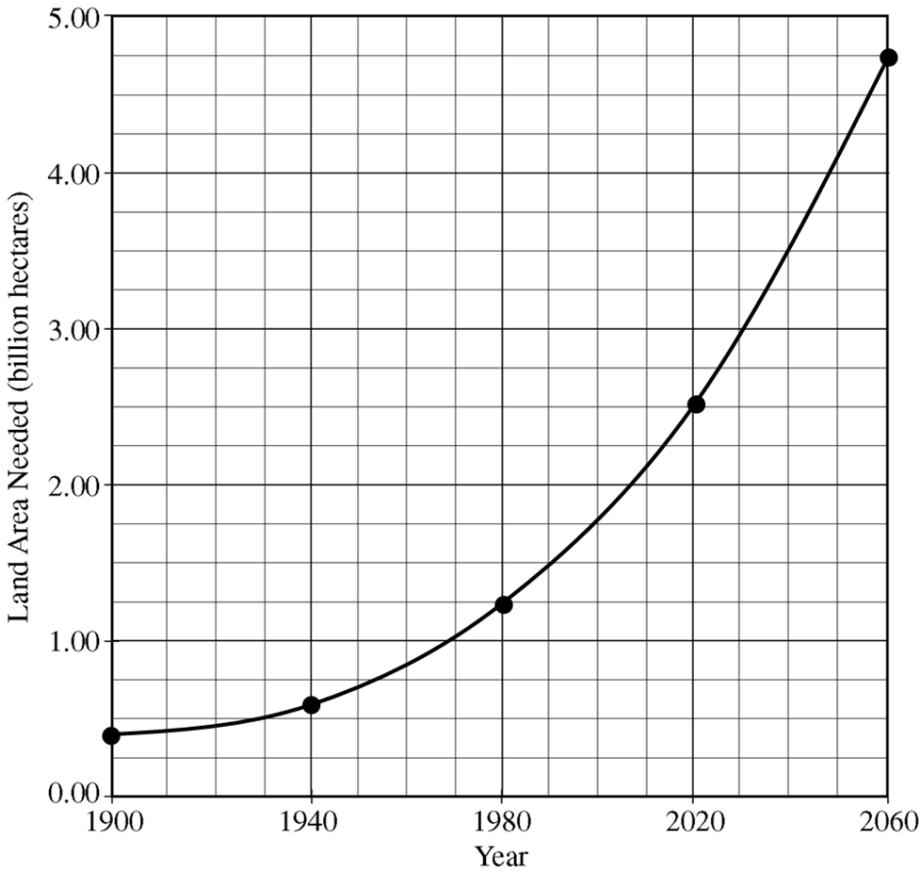
Question 4

As the world's population increases and availability of new arable land decreases, providing sufficient food for the world's human population is becoming increasingly difficult. The table below shows the area of land needed to feed the world's population from 1900 projected to the year 2060.

Year	1900	1940	1980	2020	2060
Land Area Needed (billion hectares)	0.40	0.60	1.25	2.50	4.75

(a) On the graph below, plot the data from the table above and draw a smooth curve.
(*2 points; 1 point for plotting the data and 1 point for drawing the curve*)

Students should mark the five data points and draw a smooth curve through them as shown below.



(b) Assume that the maximum arable land area on Earth is 4.00 billion hectares. Using the smooth curve that you created above, determine the year in which the human population is likely to run out of arable land for agriculture.
(1 point for a date that is consistent with the student's graph — e.g., for the graph above, the correct answer is about 2048)

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Question 4 (continued)

(c) Soil quality is a critical factor in agriculture. Identify TWO physical and/or chemical properties of soils and describe the role of each property in determining soil quality.
(*4 points; 1 point for each of the two properties and 1 point for each of the corresponding descriptions*)

Property	**Role in determining soil quality**
pH/acidity/alkalinity	• Different plants have different pH tolerances; many plants grow best in neutral soils. • Soils of higher pH are more capable of adsorbing cations (e.g., K^+, Ca^{2+}), preventing cations from being leached from soil.
Particle size/texture; soil density/type (e.g., silt, clay, sand, loam)	• Dictates soil's: o available oxygen, which is needed by plant roots/soil organisms, o ability to be worked for agriculture, o ability to hold moisture, o ability to hold nutrients, o ability to allow water to infiltrate.
Porosity/pore size	• Affects soil's ability to absorb/retain water: o Water is needed by plants for survival/growth. o If soil cannot retain water within reach of plant roots, crops will need frequent rains or irrigation. o Water cannot be used by plants if it cannot infiltrate the soil. o Water cannot be used by plants if it leaches away from plant roots. o Standing water (poor permeability) can suffocate/drown plants. o Poor permeability can lead to increased soil salinity. • Pores allow space for oxygen needed by plant roots/soil organisms for respiration/survival.
Water-holding capacity	• Water is needed by plants for survival/growth. • Water cannot be used by plants if it leaches away from plant roots. • If soil cannot retain water within reach of plant roots, crops will need frequent rains or irrigation.
Permeability/infiltration	• Water cannot be used by plants if it cannot infiltrate the soil. • Standing water (poor permeability) can suffocate/drown plants. • Poor permeability can lead to increased soil salinity.
Aeration	• Oxygen is needed by plant roots/soil organisms for respiration/survival.
Nutrient-holding capacity	• Plants need nutrients/minerals (or specific nutrients/minerals) for growth. • Minerals that readily leach from the soil (upper soil horizons) will not be available for plant growth.
Compaction	• Reduces soil's ability to absorb/retain water. • Reduces soil oxygen, which is needed for respiration by plants and soil organisms (aeration).

Question 4 (continued)

Phosphate/calcium/ nitrogen/potassium/etc. content *Note:* Students may identify two specific nutrients/minerals for 2 points.	• Plants need phosphate/calcium/nitrogen/potassium/etc. for growth/survival. • The presence of excessive amounts of zinc/copper/nitrogen/etc. can be toxic to plants (e.g., by preventing the uptake of other nutrients/minerals) and/or cause weed species to thrive.
Salinity	• Excessive salts in soil may: o inhibit water uptake by plants, o draw water out of plants (via osmosis), o make plants less resistant to disease, o cause stunted plant growth, o decrease crop yield, o cause yellowing of leaves.
Presence of organisms/organic matter/ leaf litter/humus/mulch/ crop residue	• Increases the ability of soil to retain moisture/nutrients. • O horizon prevents/minimizes evaporative water loss from the A horizon (topsoil). • Certain organisms in soil can be beneficial (e.g., earthworms) or harmful (e.g., root-eating nematodes) to agricultural crops. • Organic matter provides nutrients to the topsoil.
Friability/workability	• Dictates how readily soil can be cultivated.
Presence of pesticide residue (e.g., glyphosate)	• Can inhibit plant growth/crop production.

(d) Describe TWO viable strategies for reducing the amount of land needed for agriculture.
(*2 points; 1 point each for describing any two of the following*)

Increasing crop yield:

- The development of crops that can be grown closer together, are more resistant to pests, more resistant to weather extremes, etc., via artificial selection or GM technologies could increase crop yields.
  Note: Students may earn both points for two crop improvements.
- Cover-cropping/intercropping/strip farming/strip cropping/alley cropping/polycultivation/ allowing for multiple crops to be grown on the same plot of land/etc. could increase crop yield by using the same plot of land during different seasons/growing noncompetitive crops together to use the space between rows/inhibiting crop diseases or pests/etc.
- Use of (more effective) pesticides/fertilizers could increase crop yield.
- Instituting crop rotation to improve soil fertility could increase crop yield.

Question 4 (continued)

Decreasing the demand for agricultural land:

- Eating lower on the food chain would reduce the amount of land needed to raise livestock.
- Curbing population growth via programs that lessen the need/desire for people to have children would reduce the amount of land needed for agriculture.
- Urban/home/rooftop gardens utilize urban/residential space for growing food.
- Instituting a practice that prevents the degradation of our current agricultural land (e.g., contour farming to prevent erosion, crop rotation to maintain soil fertility, etc.) will lessen the demand for new agricultural land.
- Underground and/or multistory hydroponic facilities would provide more area for growing crops without increasing land area needed.
- Preventing food spoilage/wastage would result in less food being thrown away.
- Banning the use of agricultural crops to make fuels would allow those crops to be used for feeding people.
- Switching from cotton to hemp for textiles would provide more material per acre.
- Switching to (more efficient) crops that produce more nutrients/food/calories per acre would allow us to feed more people using less land.
- Aquaculture/raising seafood as a meat/protein substitute would lessen the need for land to sustain livestock.

(e) One problem that can result from agriculture is soil salinization.

(i) Describe how salinization occurs.
(*1 point*)

Any of the following is a correct response:

- Salinization can occur when irrigation water evaporates (or is used by plants), leaving the salts behind in the soils.
- (In arid regions), evaporation of (irrigation) water from the top layer of soil can draw water up from deeper in the soil column (via capillary action). If shallow ground water contains salts (possibly from saltwater encroachment), or if the deeper soil is high in salts, then salts will wick to the surface.
- Precipitation can pick up salts from the soil, pool in areas of poor drainage, and evaporate, leaving behind the salts.
- Misuse of salt-containing fertilizers and/or other soil amendments that contain salts (e.g., lime) may lead to soil salinization.
- Salt applied to roads can run off (or splash/spray) and contaminate roadside soil.
- Tsunamis/storm surges (e.g., from hurricanes) can deposit salts inland.

Question 4 (continued)

(ii) Describe one method to prevent or remediate soil salinization.
(*1 point*)

Any of the following is a correct response:

- Irrigate/flush with sufficient (fresh) water to leach the salts down through the soil (especially after the growing season), or wait for rain to flush the salts out of the soil.
- The use of drip irrigation/soaker hoses/etc. requires less water than traditional irrigation, resulting in a lower influx of salt (or less water loss via evaporation).
- Avoid planting crops that require a large amount of water in areas prone to salinization.
- Avoid planting crops until the salt has been flushed from the soil.
- Plant vegetation/crops that remove salt from the soil (e.g., saltbush, barley, oats).
- Improving drainage (e.g., installing drainage tiles) will prevent precipitation/irrigation water from pooling and evaporating.
- Irrigate with water that is low in salt content.
- Use more organic/salt-free fertilizers/avoid using (as much) salt-containing fertilizers and/or other soil amendments that contain salts.
- Incorporate organic material into the soil.
- Use alternatives to road salt (e.g., beet juice, sand)/avoid applying (as much) road salt.
- Plant vegetation/avoid removing vegetation that would protect inland areas from tsunamis/storm surges.