

**AP<sup>®</sup> ENVIRONMENTAL SCIENCE  
2011 SCORING GUIDELINES**

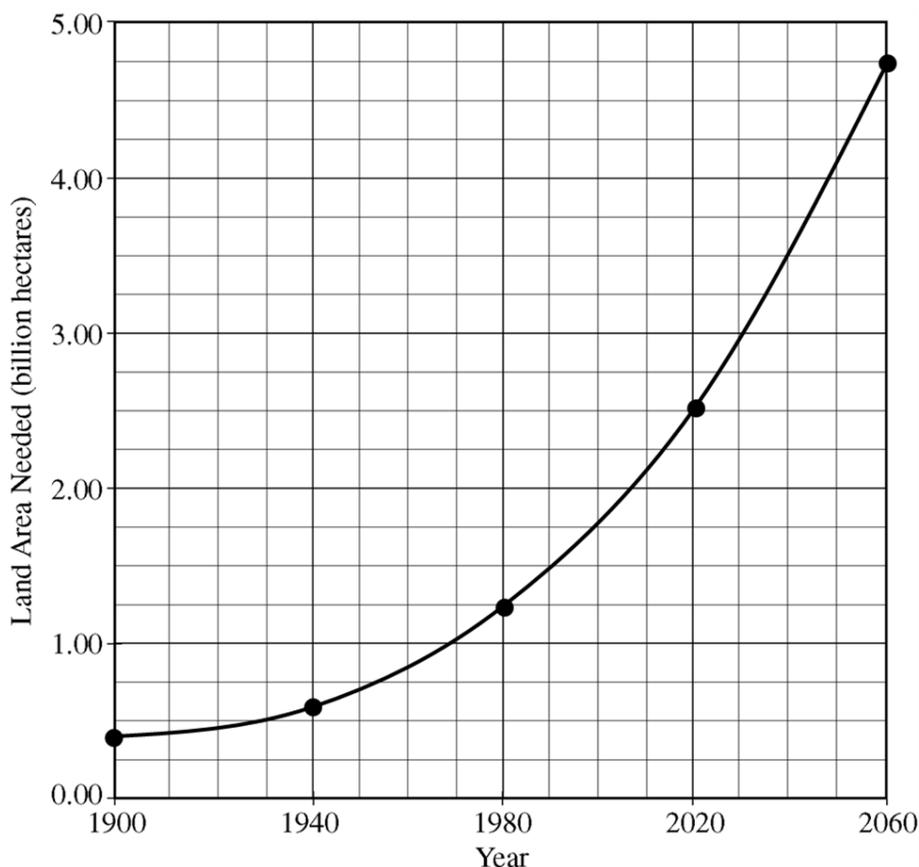
**Question 4**

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)

<b>Property</b>	<b>Role in determining soil quality</b>
pH/acidity/alkalinity	<ul style="list-style-type: none"> <li>• Different plants have different pH tolerances; many plants grow best in neutral soils.</li> <li>• Soils of higher pH are more capable of adsorbing cations (e.g., K<sup>+</sup>, Ca<sup>2+</sup>), preventing cations from being leached from soil.</li> </ul>
Particle size/texture; soil density/type (e.g., silt, clay, sand, loam)	<ul style="list-style-type: none"> <li>• Dictates soil's:               <ul style="list-style-type: none"> <li>○ available oxygen, which is needed by plant roots/soil organisms,</li> <li>○ ability to be worked for agriculture,</li> <li>○ ability to hold moisture,</li> <li>○ ability to hold nutrients,</li> <li>○ ability to allow water to infiltrate.</li> </ul> </li> </ul>
Porosity/pore size	<ul style="list-style-type: none"> <li>• Affects soil's ability to absorb/retain water:               <ul style="list-style-type: none"> <li>○ Water is needed by plants for survival/growth.</li> <li>○ If soil cannot retain water within reach of plant roots, crops will need frequent rains or irrigation.</li> <li>○ Water cannot be used by plants if it cannot infiltrate the soil.</li> <li>○ Water cannot be used by plants if it leaches away from plant roots.</li> <li>○ Standing water (poor permeability) can suffocate/drown plants.</li> <li>○ Poor permeability can lead to increased soil salinity.</li> </ul> </li> <li>• Pores allow space for oxygen needed by plant roots/soil organisms for respiration/survival.</li> </ul>
Water-holding capacity	<ul style="list-style-type: none"> <li>• Water is needed by plants for survival/growth.</li> <li>• Water cannot be used by plants if it leaches away from plant roots.</li> <li>• If soil cannot retain water within reach of plant roots, crops will need frequent rains or irrigation.</li> </ul>
Permeability/infiltration	<ul style="list-style-type: none"> <li>• Water cannot be used by plants if it cannot infiltrate the soil.</li> <li>• Standing water (poor permeability) can suffocate/drown plants.</li> <li>• Poor permeability can lead to increased soil salinity.</li> </ul>
Aeration	<ul style="list-style-type: none"> <li>• Oxygen is needed by plant roots/soil organisms for respiration/survival.</li> </ul>
Nutrient-holding capacity	<ul style="list-style-type: none"> <li>• Plants need nutrients/minerals (or specific nutrients/minerals) for growth.</li> <li>• Minerals that readily leach from the soil (upper soil horizons) will not be available for plant growth.</li> </ul>
Compaction	<ul style="list-style-type: none"> <li>• Reduces soil's ability to absorb/retain water.</li> <li>• Reduces soil oxygen, which is needed for respiration by plants and soil organisms (aeration).</li> </ul>

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**Question 4 (continued)**

Phosphate/calcium/nitrogen/potassium/etc. content <i>Note:</i> Students may identify two specific nutrients/minerals for 2 points.	<ul style="list-style-type: none"> <li>Plants need phosphate/calcium/nitrogen/potassium/etc. for growth/survival.</li> <li>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.</li> </ul>
Salinity	<ul style="list-style-type: none"> <li>Excessive salts in soil may:               <ul style="list-style-type: none"> <li>inhibit water uptake by plants,</li> <li>draw water out of plants (via osmosis),</li> <li>make plants less resistant to disease,</li> <li>cause stunted plant growth,</li> <li>decrease crop yield,</li> <li>cause yellowing of leaves.</li> </ul> </li> </ul>
Presence of organisms/organic matter/leaf litter/humus/mulch/crop residue	<ul style="list-style-type: none"> <li>Increases the ability of soil to retain moisture/nutrients.</li> <li>O horizon prevents/minimizes evaporative water loss from the A horizon (topsoil).</li> <li>Certain organisms in soil can be beneficial (e.g., earthworms) or harmful (e.g., root-eating nematodes) to agricultural crops.</li> <li>Organic matter provides nutrients to the topsoil.</li> </ul>
Friability/workability	<ul style="list-style-type: none"> <li>Dictates how readily soil can be cultivated.</li> </ul>
Presence of pesticide residue (e.g., glyphosate)	<ul style="list-style-type: none"> <li>Can inhibit plant growth/crop production.</li> </ul>

**(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.

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### 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.

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**Question 4 (continued)**

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

*(1 point)*

Any of the following is a correct response:

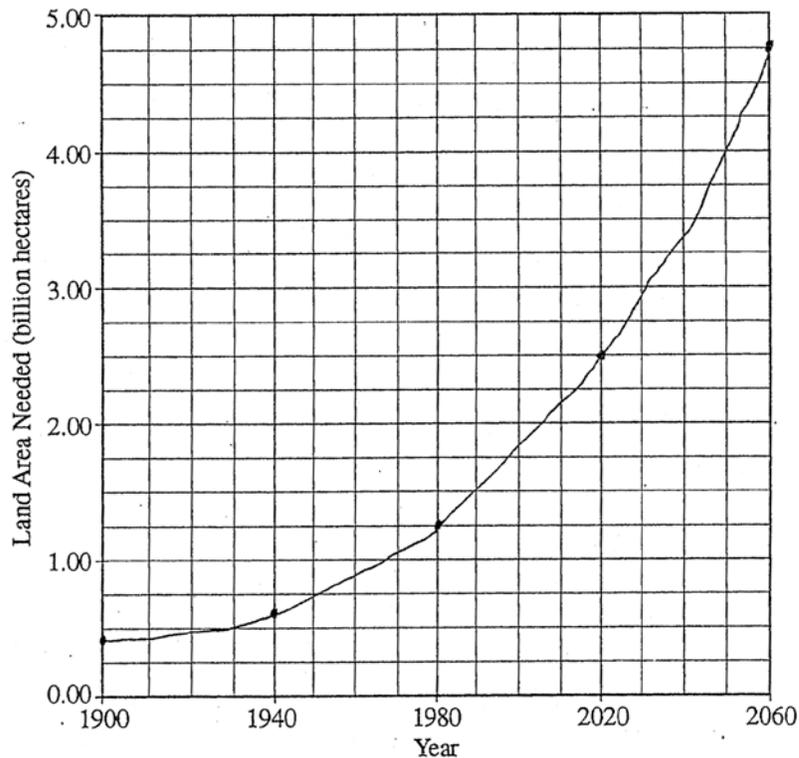
- Irrigate/flush with sufficient (fresh) water to leach the salts down through the soil (especially after the growing season), or wait for rain to flush the salts out of the soil.
- The use of drip irrigation/soaker hoses/etc. requires less water than traditional irrigation, resulting in a lower influx 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.

4A,

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.

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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.



- (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.
- (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.
- (d) Describe TWO viable strategies for reducing the amount of land needed for agriculture.
- (e) One problem that can result from agriculture is soil salinization.
- (i) Describe how salinization occurs.
  - (ii) Describe one method to prevent or remediate soil salinization.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 4

(b) Humanity would be running out of arable land by around 2050 according to my smooth curve.

(c) A soil's permeability ~~is~~ <sup>influences</sup> how well agriculture can thrive in a particular area. If the soil isn't permeable enough, water cannot reach the roots of ~~plants~~ <sup>crops</sup> and they will die. If the soil is too permeable, ~~it~~ <sup>it</sup> cannot hold water well and crops will not get enough water and will die. Therefore, ~~a~~ <sup>a</sup> good soil is loamy, ~~is~~ <sup>is in between these two</sup> and ~~is~~ <sup>is</sup> extremes.

Salinity is a critical factor in determining ~~the~~ <sup>soil</sup> quality. ~~Improper~~ <sup>Improper</sup> irrigation techniques ~~or~~ <sup>or</sup> standing water can ~~cause~~ <sup>cause</sup> salt to build up to an extent where it is impossible for ~~any~~ <sup>any</sup> crop to grow in the soil. ~~High~~ <sup>High</sup> salinity prevents ~~plants~~ <sup>plants</sup> from properly receiving and holding water.

(d) ~~By~~ <sup>By</sup> reducing the amount of meat we eat, humanity can reduce the amount of land needed for agriculture. Because a significant amount of land and crops is needed to feed and care for farm animals, by eliminating meat from our diets we can produce more crops for humans. This would feed more people because ~~we can~~ <sup>we can</sup> receive more energy from eating producers than primary consumers. If we use more methods of birth control and educate more women on birth control then we will need less land for agriculture because we will have fewer people to feed. With less demand, we will ~~not~~ <sup>need</sup> to grow fewer crops. Also, genetically engineered crops can increase crop ~~yield~~ <sup>yields</sup> ~~but~~ <sup>but</sup> without using more space and planting crops where they could previously not grow.

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4A<sub>3</sub>

ADDITIONAL PAGE FOR ANSWERING QUESTION 4

① i Soil salinization can occur from improper irrigation that causes a build up of ~~salt~~ salt in the soil. Using too much water for irrigation or allowing ~~standing water~~ <sup>standing water</sup> on agricultural areas builds up salt in the soil. ii By using drip-irrigation, ~~the~~ <sup>only</sup> the amount of water each plant needs is used and the salt built up by the water is minimal.

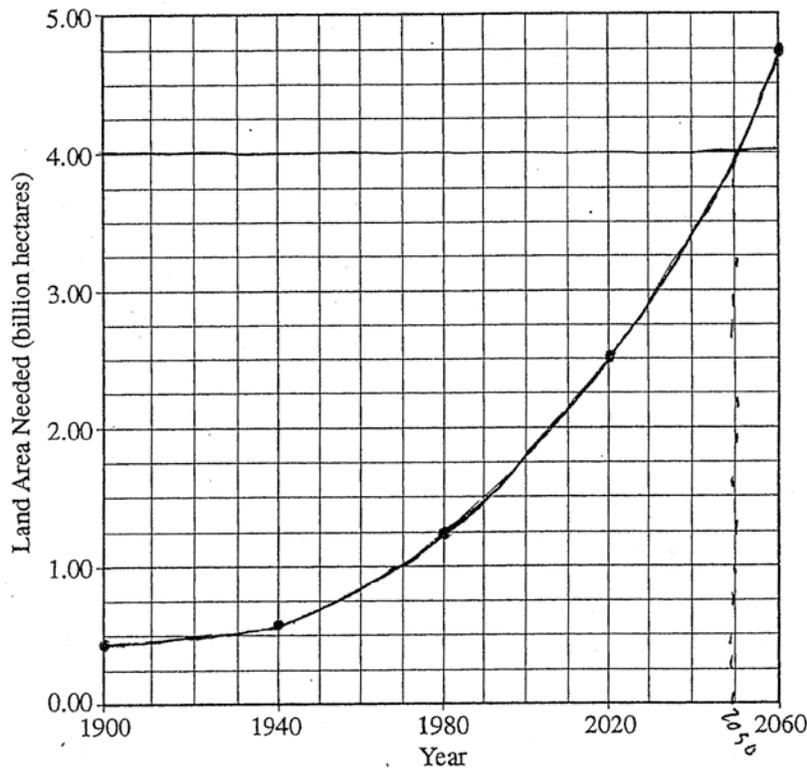
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4B,

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.

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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.



- (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.
- (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.
- (d) Describe TWO viable strategies for reducing the amount of land needed for agriculture.
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- (i) Describe how salinization occurs.
  - (ii) Describe one method to prevent or remediate soil salinization.

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a) see graph

b) If the maximum ~~the~~ amount of arable land on earth is 4.00 billion hectares, then the earth will run out of arable land in about the year 2050.

c) • Soil must have a neutral pH to effectively grow crops. While a few species of plants thrive in acidic or basic soils, most plants require a neutral pH to thrive in, the more neutral the soil, the better.

• The soil must be able to hold water so that the plant can easily take up water, but should also let some water drain through, to recharge groundwater supplies and so that the plant isn't overwatered. ~~The~~ A good example of a balanced soil like this is loam, which is made up of equal parts clay, sand, and silt.

d) • One strategy for reducing <sup>the</sup> amount of land needed for agriculture would be for more people to become vegetarians, or just eat less meat. When we produce meat to be consumed, it requires not only land for the cattle, but also land to grow the cattle's food. By eliminating meat from our diet, we could use the land for raising the cattle and their food for simply growing our food.

• Another strategy would be to decrease the human population, thereby reducing the

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amount of food needed, and the amount of land required to grow it.

e) i. Salinization occurs after all the nutrients in the soil have been used up after too many crops have been planted without letting the soil rest.

ii. One method to prevent salinization is crop rotation, where crops are rotated between different fields in order to let the soil rest and regain its nutrients naturally.

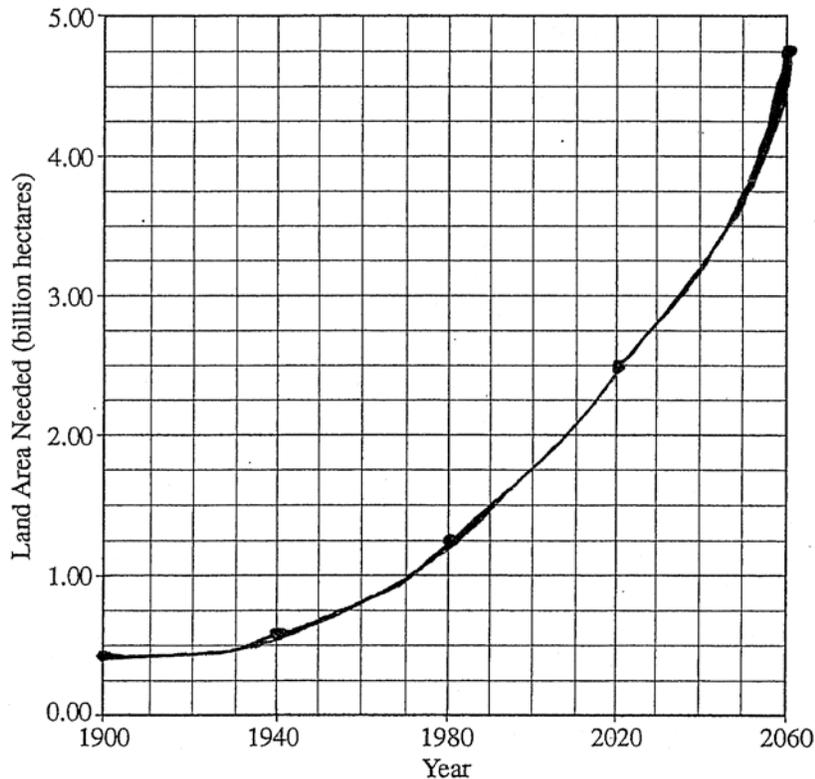
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4C,

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.

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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.



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- (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.
- (d) Describe TWO viable strategies for reducing the amount of land needed for agriculture.
- (e) One problem that can result from agriculture is soil salinization.
- (i) Describe how salinization occurs.
  - (ii) Describe one method to prevent or remediate soil salinization.

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Assuming the maximum arable on Earth is 4.00 billion hectares, according to the graph the human population will run out of arable land at around 2055.

A physical property of soil that determines soil quality is how permeable it is. If the soil can't hold water it has bad quality but also if it holds too much than it could drown the plant. Another property of soil that determines soil quality is the amount of nutrients it contains. The soil should contain enough nutrients that it helps the plant that is planted in it.

Two strategies for reducing the amount of land needed for agriculture are planting multiple crops next to each other to reduce the amount of space needed, and another strategy is planting different crops during different seasons to ensure that the land is always ~~being~~ being used.

Salinization occurs from acidic things ~~being~~ being absorbed into the soil. A method to prevent or remediate soil salinization is to have the soil absorb something that counteracts the acid.

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## 2011 SCORING COMMENTARY

### Question 4

#### Overview

The intent of this question was to have students demonstrate their ability to graph and interpret data and to demonstrate their knowledge of soil properties, agricultural strategies that can be used to reduce the need for arable land, and the process of soil salinization.

#### Sample: 4A

**Score: 10**

Two points were earned in part (a): 1 for plotting the data correctly and 1 for drawing the smooth curve correctly. One point was earned in part (b) for determining from the graph that humans will likely run out of arable land for agriculture in 2050. Four points were earned in part (c): 1 for identifying permeability as a soil property, 1 for noting that permeability affects accessibility of water to plants for survival, 1 for identifying salinity as a soil property, and 1 for indicating that high salinity prevents proper uptake of water by plants. Two points were earned in part (d): 1 for indicating that we can produce more crops for humans instead of using those crops to feed animals if we eliminate meat from our diet and 1 for indicating that birth control and birth control education will result in fewer mouths to feed and thus in less need for agricultural land. One point was earned in part (e) for indicating that drip-irrigation will decrease the amount of water needed, thus minimizing salt buildup. No point was earned for the description of how salinization occurs, because the student does not explain that the water evaporates.

#### Sample: 4B

**Score: 8**

Two points were earned in part (a): 1 for plotting the data correctly and 1 for drawing the smooth curve correctly. One point was earned in part (b) for determining from the graph that humans will likely run out of arable land for agriculture in 2050. Four points were earned in part (c): 1 for identifying pH as a soil property, 1 for noting that most plants require a neutral pH to thrive, 1 for identifying ability to hold water as a soil property, and 1 for indicating that although soil must be able to hold water so plants can take it up, the soil must also allow some water to drain away in order to prevent overwatering of plants. One point was earned in part (d) for indicating that meat for human consumption requires land for the cattle themselves and land for growing the cattle's food, and that this land could instead be used for growing our own food. No point was earned for indicating a strategy "to decrease the human population," because there is no explanation of how to do so. No points were earned in part (e).

#### Sample: 4C

**Score: 6**

Two points were earned in part (a): 1 for plotting the data correctly and 1 for drawing the smooth curve correctly. One point was earned in part (b) for determining from the graph that humans will likely run out of arable land for agriculture in 2055. Two points were earned in part (c): 1 for identifying permeability as a soil property and 1 for indicating that soil with poor permeability could drown plants. No point was earned for identifying nutrient content as a soil property, because a specific nutrient is not identified. One point was earned in part (d) for explaining that the strategy of planting different crops during different seasons would ensure that the land would be productive year-round. No point was earned for the strategy of "planting multiple crops next to each other," because the student does not explain that these crops must be compatible with one another. No points were earned in part (e).