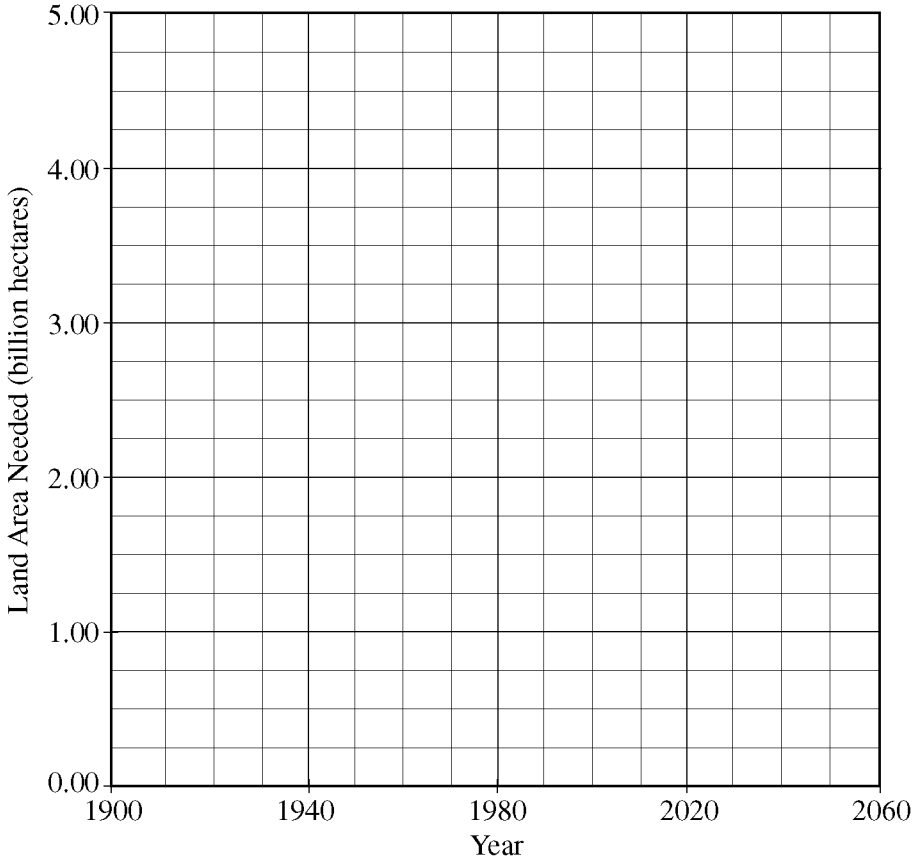
4. As the world's population increases and availability of new arable land decreases, providing sufficient food for the world's human population is becoming increasingly difficult. The table below shows the area of land needed to feed the world's population from 1900 projected to the year 2060.

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.



(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.

GO ON TO THE NEXT PAGE.

AP® ENVIRONMENTAL SCIENCE
2011 SCORING GUIDELINES

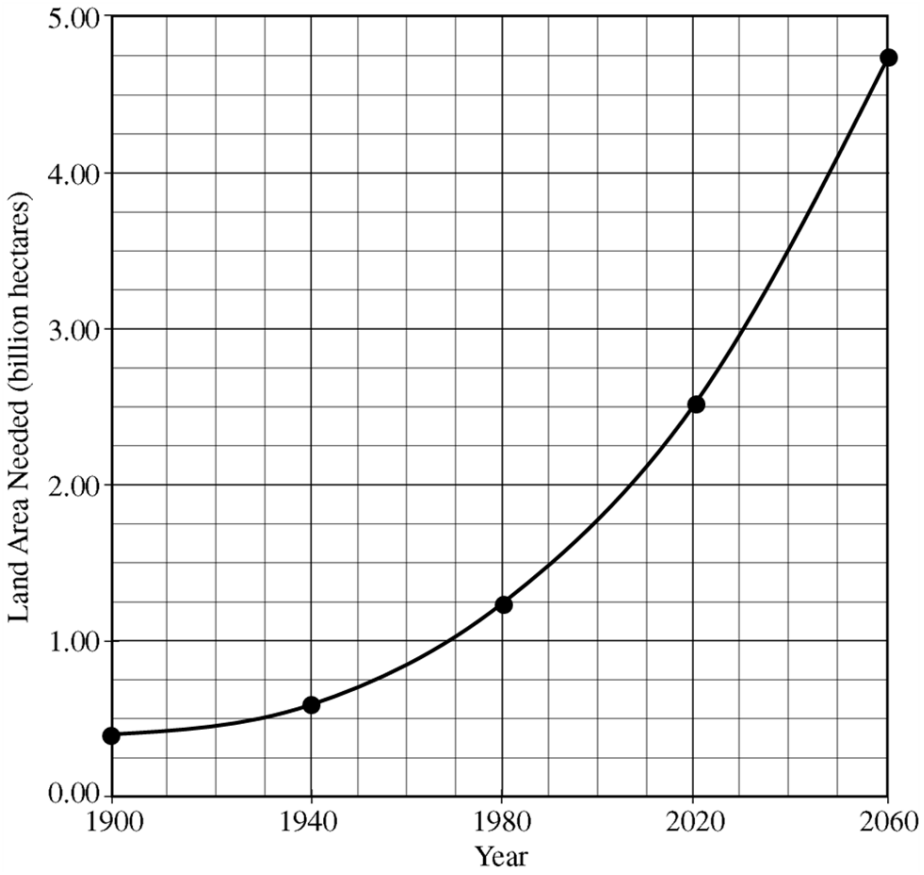
Question 4

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)

AP® ENVIRONMENTAL SCIENCE
2011 SCORING GUIDELINES

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.