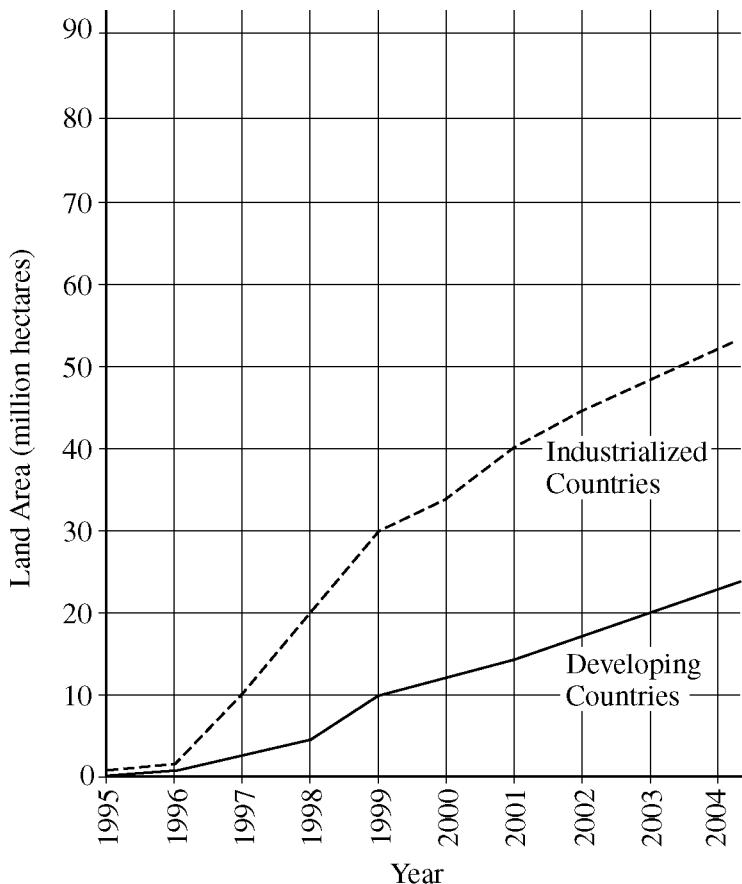


2009 AP® ENVIRONMENTAL SCIENCE FREE-RESPONSE QUESTIONS

4. The major issues in modern agriculture include the use of genetically modified (GM) crops and the implementation of sustainable agricultural practices. The following graph shows the increase in the use of GM crops in both developing and industrialized countries from 1995 to 2004.



- (a) Reply to the following questions based on the data in the graph above.
- Calculate the increase in the area of land used for growing GM crops in developing countries from 1999 to 2003. Express your answer as a percentage of the 1999 value.
 - Calculate the annual rate of increase in land area used for growing GM crops in industrialized countries from 1997 to 1999.
 - Using the rate you calculated in part (ii), project the area of land that would have been expected to be used for GM crops in industrialized countries in 2004.
 - Identify one likely cause for the difference between the projected land area for GM crops in industrialized countries in 2004 and the actual land area for GM crops in industrialized countries in 2004.

2009 AP® ENVIRONMENTAL SCIENCE FREE-RESPONSE QUESTIONS

- (b) Describe one environmental advantage and one environmental disadvantage of using GM crops.
- (c) Describe one economic advantage and one economic disadvantage of using GM crops.
- (d) A healthy soil ecosystem is of primary importance in sustainable agriculture. Describe TWO viable agricultural practices that farmers can use to maintain or improve soil quality.
- (e) Identify and describe one environmental advantage and one economic advantage of consuming locally grown produce.

STOP

END OF EXAM

**AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES**

Question 4

(a) Reply to the following questions based on the data in the graph.

Four points can be earned: 1 point for the correct answer in each section.

- (i) Calculate the increase in the area of land used for growing GM [genetically modified] crops in developing countries from 1999 to 2003. Express your answer as a percentage of the 1999 value.**

1999 (10 million hectares) to 2003 (20 million hectares)
Increase of 10 million hectares = 100 percent increase

- (ii) Calculate the annual rate of increase in land area used for growing GM crops in industrialized countries from 1997 to 1999.**

1999	30 million hectares
<u>1997</u>	<u>10 million hectares</u>
2 years	20 million hectares $20 \text{ million ha/2yr} = 10 \text{ million ha/yr}$

Must have units of "hectares" or "hectares/yr"

Note: Percentage answer accepted only if both years are calculated as independent percentages.

First year 100 percent Second year 50 percent Ave. Ann. 75 percent

- (iii) Using the rate you calculated in part (ii), project the area of land that would have been expected to be used for GM crops in industrialized countries in 2004.**

1999 -----	30 million hectares
<u>5 years</u> <u>10 million hectare increase/yr</u>	<u>50 million hectares</u>
2004	80 million hectares (<i>must have units</i>)

Note: Students who incorrectly calculate (ii) can still get points if the solution is correct in (iii).

For example: 5 million hectares/year in (ii)

5 years @ 5 million hectares/year = 25 million hectares, for a total 55 million hectares.

- (iv) Identify one likely cause for the difference between the projected land area for GM crops in industrialized countries in 2004 and the actual land area for GM crops in industrialized countries in 2004.**

Genetically modified crops faced:

- Increased public resistance (toward perceived risks, due to increased awareness following labeling of products)
- Decreasing market demand for products containing genetically modified organisms (GMOs)
- Governmental regulation/controls/limitations/bans that limited the planting/use of GM crops

Note: "Decrease in available land" is not acceptable.

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2009 SCORING GUIDELINES**

Question 4 (continued)

(b) Describe one environmental advantage and one environmental disadvantage of using GM crops.

Two points can be earned: 1 point for a description of a viable advantage and 1 point for a description of a viable disadvantage.

**Environmental Advantages: 1 point
(Score only the first advantage provided by student)**

Higher yields per acre and hence less acreage needed/impacted by agriculture

Permits low-tillage agriculture (due to herbicide resistance in GM crops), which:

- Reduces soil exposure/erosion
- Reduces energy consumption associated with farm machinery (plowing, harrowing, etc.)
- Can reduce evaporative water loss

GM crops may exhibit:

- Lower fertilizer requirements, which reduces negative impacts of fertilizers
- Insect resistance and the associated reduced impact of insecticide/pesticide use/production/exposure
- Drought resistance and the associated decreased need for irrigation
- Disease resistance and the associated decreased need for fungicide applications
- Salinity tolerance, which decreases the need for flushing of soils with water
- Frost resistance, which extends seasonal productivity and decreases crop loss
- Perennial life span (rather than annual), which reduces the need for tillage (see above)
- Firmer tissues/peels/shells reduce waste as a result of increased shelf life and reduced spoilage

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2009 SCORING GUIDELINES**

Question 4 (continued)

**Environmental Disadvantages: 1 point
(Score only the first disadvantage provided by student)**

Low-tillage agriculture often depends on:

- High dosage/frequent application of herbicides to control competitive weeds that are normally controlled by tillage

GM crops with:

- Insect resistance (e.g., Bt gene) may impact beneficial insects (e.g., pollen toxic to monarch butterflies)
- Drought-resistance gene may lead to agricultural use of currently marginal, semi-arid areas, leading to increased human pressures/loss of natural landscape
- Salinity-tolerance gene may lead to agricultural use of currently marginal, saline soils, leading to increased human pressures/loss of natural landscape
- Altered genes may impact human health with altered proteins and/or subsequent toxins

Native plant diversity may be impacted by the spread of genes to nonengineered crops.

Higher yields per acre often require higher inputs (fertilizer, etc.) and often lead to greater soil depletion and erosion.

GM crops are often engineered to have lower genetic variability than non-GM crops, thereby making GM crop monocultures more vulnerable to mass mortality than non-GM crop monocultures exposed to disease or pest outbreaks or severe environmental changes. (**Note:** To earn this point, the student must clearly contrast GM and non-GM crops and emphasize genetic variability and monoculture agriculture.)

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2009 SCORING GUIDELINES**

Question 4 (continued)

(c) Describe one economic advantage and one economic disadvantage of using GM crops.

Two points can be earned: 1 point for a description of a viable economic advantage and 1 point for a description of a viable economic disadvantage.

**Economic Advantage: 1 point
(Score only the first advantage provided by student)**

For farmers specifically

Permits low/reduced-tillage agriculture resulting in:

- Reduced soil erosion
- Retention of soil nutrients
- Reduced energy consumption associated with farm machinery (plowing, harrowing, spraying, etc.)
- Reduced water loss that lowers associated costs
- Reduced greenhouse gas emissions from agricultural activities and associated costs (carbon sequestration)

Increased profits/reduced costs due to use of GM crops that have:

- Higher yields per acre
- Lower fertilizer/pesticide/herbicide requirements
- Insect resistance, resulting in reduced insecticide cost
- Disease resistance, resulting in reduced fungicide/viral control cost
- Healthier appearance (e.g., reduced viral spotting of skin of papaya)
- Drought resistance, resulting in lower costs for irrigation or expanded land area under cultivation
- Saline resistance, resulting in lower cost for irrigation/mitigation or increased use of marginal lands
- Less worker exposure to fertilizer/pesticides/herbicides and lower associated health-care costs
- Increased nutritional value
- Pharmacological value
- Frost resistance—extends seasonal productivity
- Firm tissue/peels/shells—less spoilage of crops in transit

For society in general

- Decreased health-care costs:
 - Due to reduced worker exposure to pesticides
 - Better-nourished people (“golden rice”)

**AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES**

Question 4 (continued)

**Economic Disadvantages: 1 point
(Score only the first disadvantage provided by student)**

For farmers specifically

Higher yields per acre often lead to greater soil depletion, requiring higher costs of mitigation.

Low-tillage agriculture often depends on:

- Costly high dosage/frequent application of herbicides to control competitive weeds that are normally controlled by tillage

Decreased profits/increased costs due to use of GM crops that:

- Have increased fertilizer demand to reach yield potential
- Require investment in a new generation of pesticides because the GM crop has promoted target insect pest resistance
- Increase the amount and frequency of pesticide applications to mitigate nontarget pests whose virulence increases (when pests targeted by the GM crops are suppressed)
- Have patented seeds (which commit the farmer to annual purchase of seeds that are often too expensive for poor farmers)
- Have sterile seeds, committing the farmer to annual seed purchases
- Risk consumer rejection/import restrictions that result in lower demand for GM crops

For society in general

Costs of/for:

- Tracking and labeling GM crops in the food supply
- Litigation surrounding use of GM crops
- Controlling pest species to which the new gene has been inadvertently transferred
- Unexpected health issues related to GM crops
- Research and development

**AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES**

Question 4 (continued)

(d) A healthy soil ecosystem is of primary importance in sustainable agriculture. Describe TWO viable agricultural practices that farmers can use to maintain or improve soil quality.

Two points can be earned: 1 point for each description of a viable agricultural practice. Score only the first two answers provided by the student; answers must provide a description of the practice or/and include a linked advantage.

Practice	Description	Advantage
Fertilizing or supplementing	Application of nutrients (compost, organic, inorganic)	<ul style="list-style-type: none">For optimum nutrient availabilityLess-soluble/mobile nutrients in organic fertilizer
Monitoring or adjusting	<ul style="list-style-type: none">Doing soil testsBalancing soil nutrients	<ul style="list-style-type: none">Optimum nutrient (N, P, K, Ca, Fe, etc.)/pH balance
Contouring or terracing	Building/installing water bars, terraces, etc.	<ul style="list-style-type: none">Reduces soil erosion
Crop rotation	Planting different crops in subsequent planting periods	<ul style="list-style-type: none">Lower herbicide/insecticide requirementsAdds nutrients back to the soilTakes advantage of nitrogen-fixers (e.g., legumes)
Cover crops	<ul style="list-style-type: none">Interspersing crops/planting between the rowsPlanting cover vegetation during a fallow period	<ul style="list-style-type: none">Adds nutrientsReduces erosion
Windbreaks	Planting rows of trees or shrubs	<ul style="list-style-type: none">Lowers soil loss to wind erosionTraps moisture of winter snows
Mulching	Applying organic matter to the surface of the field/soil	<ul style="list-style-type: none">Lowers water lossIncreases water-holding capacityIncreases nutrient availabilityIncreases permeability/infiltration
Reduced or no tillage	Planting with reduced or no mechanical turning of the soil	<ul style="list-style-type: none">Decreases evaporationDecreases soil erosion
Fallowing	Allowing soil to rejuvenate with a noncrop year; resting soil	<ul style="list-style-type: none">Rests/recharges soilAdds nutrientsLowers erosion

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2009 SCORING GUIDELINES**

Question 4 (continued)

Practice	Description	Advantage
Small-scale, slash-and-burn agriculture (<i>milpa</i> ; swidden)	<ul style="list-style-type: none"> Forest is cut in small patches Some shrubs/herbaceous plants remain Crops planted together among existing vegetation 	<ul style="list-style-type: none"> Conserves soil nutrients Allows nutrients time to replenish Erosion losses are minimized
Tiling	Installing underground drainage	<ul style="list-style-type: none"> Reduces water saturation Reduces capillary rise of salts
Polyculture/inter-cropping	Use of a diversity of species to take advantage of beneficial interactions	<ul style="list-style-type: none"> Lowers soil exposure Takes advantage of different root depths Breaks monoculturing and its negative effects Takes advantage of attributes of multiple species (nitrogen-fixer, insect resistance)
Rotational grazing	Moving cattle to benefit grassland health	<ul style="list-style-type: none"> Ensures healthy regeneration of grasslands
GM crops	Planting GM crops (must suggest soil improvement)	<ul style="list-style-type: none"> Environmental advantage must refer to improving soil quality, such as the nitrogen-fixing quality of GM crops
Pesticide reduction	Eliminate overuse of pesticides or fertilizers or herbicides	<ul style="list-style-type: none"> Removes products that compromise soil ecology or health
Tillage or soil structure alteration	<ul style="list-style-type: none"> Mechanical or physical alteration Harrowing, plowing in loam, sand, clay, organic matter to improve soil attributes 	<ul style="list-style-type: none"> Aerates soil Increases permeability Increases water/nutrient holding capacity, permeability, workability
Irrigation	Distribution of water (pumps, piping, wells, center pivot)	<ul style="list-style-type: none"> Increases effectiveness of fallowing Increases decay/composting of vegetation Drip irrigation avoids oversaturation/waterlogging and/or salinization problems
Permaculture	Designing the agricultural system to mimic a healthy soil ecosystem (includes many other practices, e.g., composting, intercropping)	<ul style="list-style-type: none"> Increases ecological diversity associated with cropping landscape Reduces erosion/nutrient loss and/or increases nutrient retention, soil biota, humus

**AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES**

Question 4 (continued)

(e) Identify and describe one environmental advantage and one economic advantage of consuming locally grown produce.

Two points can be earned: 1 point for an environmental advantage and 1 point for an economic advantage.

**Environmental Advantages: 1 point
(Score only the first advantage provided by student)**

Decreased transportation of food, which results in:

- Decreased fossil fuel consumption
- Decreased greenhouse gases, climate impacts, or carbon footprint
- Decreased combustion-related air pollutants/emissions (GHG, VOCs, ozone, particulates, smog)
- Decreased extraction impacts (drilling, transport, spills)
- Decreased transport impacts (oil spills)
- Decreased transport of pest species with crops

Consumers can more easily influence environmental choices of growers by:

- Supporting organic or permacultural practices and community-supported agriculture (CSA)
- Knowing what farming strategies are used (encouraging low pesticide or herbicide use)

Consumers can avoid packaging waste

Not exporting nutrients—nutrients remain locally compostable

**Economic Advantages: 1 point
(Score only the first advantage provided by student)**

Lower cost associated with:

- Transportation (fossil fuels, vehicle maintenance)
- Storage (warehousing, refrigeration, ripening agents, preservation)

Boost in local economy with:

- Revenues remaining in local area
- Support for local labor or increased number of jobs
- Use of community-supported agriculture (CSA)

Lower health-care costs associated with local food because it can be more nutritious (less time in transit, picked in riper condition)